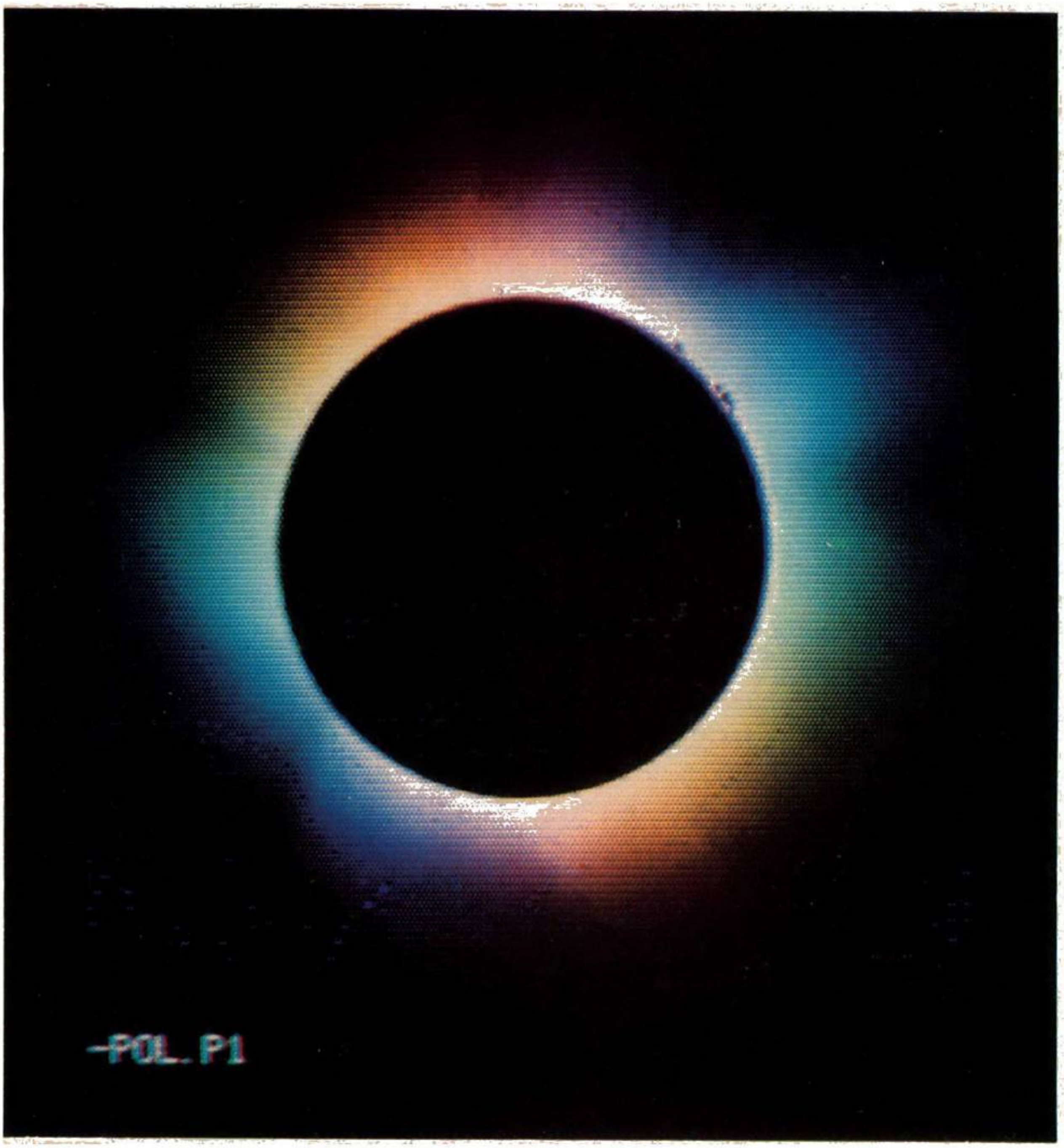
ASTRONOMY

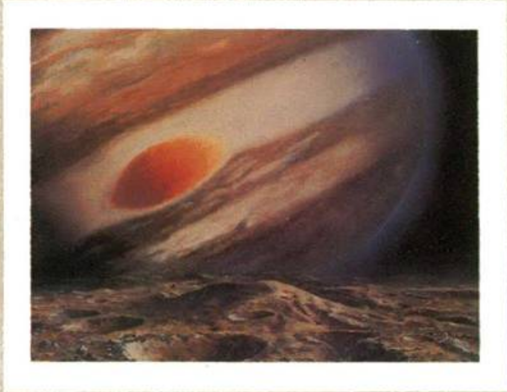
JANUARY 1978 $1.50



NEW FROM

To you, our readers, ASTRONOMY now offers a series of 8 dynamic, new, full color Art Reprints of some of the best paintings — by artists John Clark, Victor Costanzo, James Hervat, Mark Paternostro, Adolf Schaller and Rick Sternbach — that have appeared in ASTRONOMY Magazine.

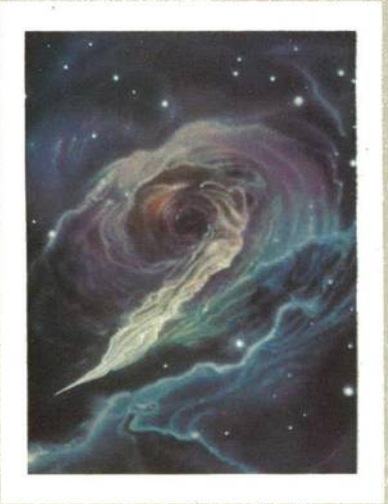
Adding to the drama, depth and realism of each piece, these Art Reprints are printed on 80 lb. linen finish paper, and are coated with a high gloss varnish. And each reprint is surrounded with a one inch white border,



Actual Size 17 x 22

Jupiter From Io

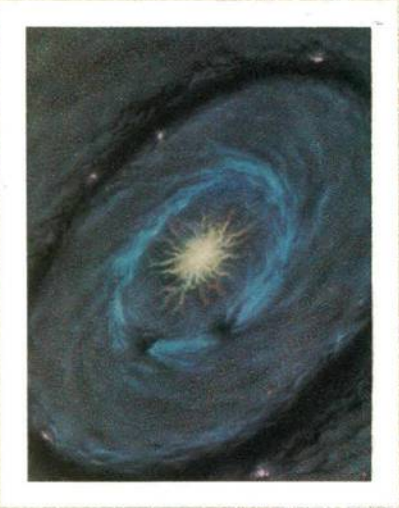
This dramatic painting reveals an incredible vista that man may never witness first hand: the incredible bulk of Jupiter looming over the surface of its satellite Io. Located deep within Jupiter's intense magnetic field, Io is one of the most lethal places in the entire solar system. To view this scene, we must rely on the imagination of artist John Clark.



Actual Size 17 x 22

Black Hole

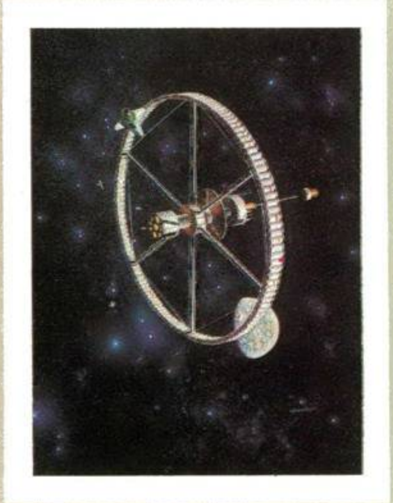
A nearly invisible small black hole speeds through a dense interstellar cloud of gas and dust, leaving behind a trail of gravitationally disturbed material. The infalling material becomes hot and emits light as it drains out of the known universe. Artist Mark Paternostro speculates on the appearance of these still undetected objects.



Actual Size: 17 x 22

The Galactic Core

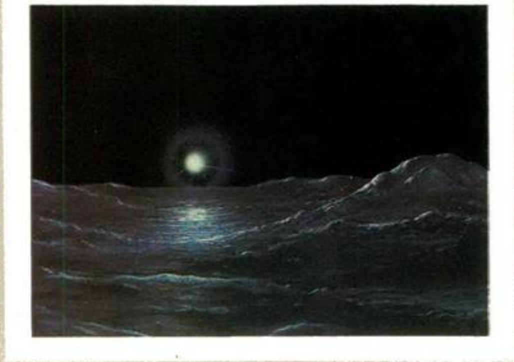
The nucleus of our galaxy is one of the true unknowns in our universe. Recent radio and infrared observations suggest that two titanic swirling rings of gas and dust occupy the core of our galaxy. These rings were apparently produced by an explosion 10 million years ago. Victor Costanzo's painting indicates that actual conditions at the galaxy's center remain a mystery.



Actual Size 17 x 22

Colony in Space

What will space stations and orbiting colonies of the future look like? Artist Rick Sternbach provides an ingenious answer in his painting of a mile wide space station wheeling slowly above the gibbous Earth. Shuttle rockets near the station's hub bring ore from the lunar surface for refinement in the station's zero gravity manufacturing center.



Actual Size 17 x 22

Pluto

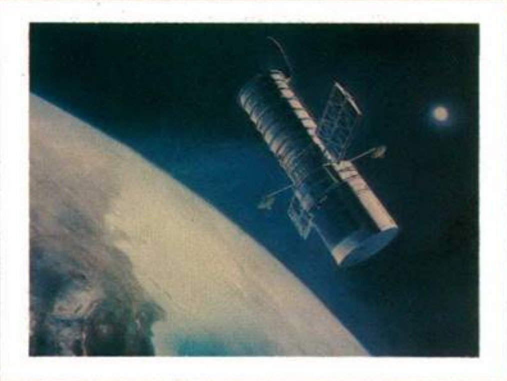
The setting sun glints off a low plain of methane ice on the surface of the smallest and most distant planet, Pluto. The cold and forbidding scene — completely alien to Earth dwellers — comes to life in this rendition by James Hervat. The mysteries of Pluto are brought home to us as we stand and gaze back toward our incredibly distant sun.

ASTRONOMY

making it easier to frame, or suitable for hanging as is.

These magnificent, colorful Art Reprints are available for only $2.00 each, plus $1.00 per order for shipping and handling. Or if you prefer, by ordering a full set of 8 Art Reprints, you can take advantage of our special price of $12.75 for a set of 8 — that's a 20% savings!! — plus $1.00 per order for shipping and handling.

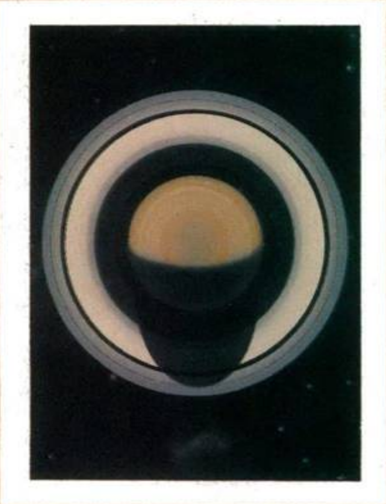
So don't wait . . . Order your ASTRONOMY Art Reprints today!



Actual Size: 17 x 22

Space Telescope

Painted by John Clark from official NASA blueprints, this poster depicts the Space Telescope — a powerful 94 inch (2.4 meter) aperture telescope due to be launched during the early 1980s by NASA's Space Shuttle. This is an accurate depiction of an instrument that will revolutionize man's view of the universe during the decades it remains in operation.



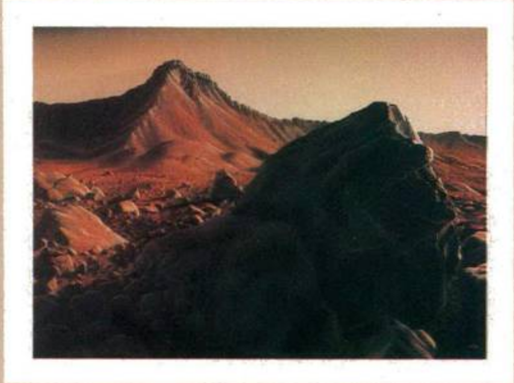
Actual Size: 17 x 22

Saturn

In an unusual perspective from above the north pole of Saturn, we can identify the planet's three main rings and their sizes relative to Saturn itself, enabling us to grasp the vast extent of Saturn's ring system. This remarkable painting by Adolf Schaller gives us a view of the planet not obtainable from Earth.

Vallis Marineris

Photographs returned from Mariner and Viking probes revealed for the first time the immensity of Vallis Marineris, the equatorial canyon of Mars. This painting by Adolf Schaller — meticulously transcribed from overhead Viking photos — takes us to the foot of a blanket of landslide rubble in the canyon itself.



Actual Size: 17 x 22

Quantity	Item	Price	Total
	Jupiter From Io	@ 2.00	$
	Black Hole	@ 2.00	$
	Colony in Space	@ 2.00	$
	The Galactic Core	@ 2.00	$
	Pluto	@ 2.00	$
	Saturn	@ 2.00	$
	Vallis Marineris	@ 2.00	$
	Space Telescope	@ 2.00	$
	Full Set of 8 Art Reprints (one of each the above)	@ $12.75	$
PLUS SHIPPING, HANDLING PER ORDER			$1.00
		TOTAL AMOUNT	$

Sorry – Art Reprints may not be billed.

Send check or money order to:
ASTRONOMY
411 E. Mason St., 6th Floor
Milwaukee, WI 53202

Date: ____________________

Name ______________________________
(please print)

Address ______________________________

City ____________ State/Prov. ____________ Zip ____________

William K. Hartmann and Wadsworth Publishing Company invite you on an exciting tour of the universe in Hartmann's captivating new introductory astronomy book

ASTRONOMY: THE COSMIC JOURNEY

Join us on, not one, but three fascinating journeys through the world of astronomy: through *space* (from our own earth-moon system to the edge of the universe), through *cosmic time* (back to the beginning of the cosmos 12 to 30 billion years ago), and through *historical time* (the record of man's discoveries).

A gifted author (MOONS AND PLANETS and THE NEW MARS) and frequent contributor to numerous national science magazines, Hartmann narrates a story more exciting that any science fiction —the *real* story.

Here's what a few prepublication reviewers had to say about ASTRONOMY: THE COSMIC JOURNEY:

❝Without doubt, Hartmann is one of the great writers in science today. I am simply captivated by his manuscript. I can't remember previously having gone straight through that many pages of a textbook, still feeling like I'd be glad to see what came next.❞
Robert J. Chambers
Pomona College

❝Indeed, I forgot that I was reviewing a text and found myself reading it for pleasure . . . the writing style is excellent—engaging, graceful, with the right touch of humor . . . it reads like a polished novel.❞
Richard C. Smith
University of West Florida

❝I was quite impressed with the clarity and ingenuity of many of the sections of the book.❞
Scott Tremaine
California Institute of Technology

Astronomy:
The Cosmic Journey
Hartmann

FEATURES

color section of 32 full-color plates chosen for instructive and comparative qualities • plus 375 photos printed in a special duotone (two-color) process for greatly enhanced clarity, contrast, and richness • scientifically realistic paintings by today's leading ''space artists''—Chesley Bonestell, Adolf Schaller, others • many photos and paintings published for the first time • 190 drawings • easy-to-read, 3-column ''magazine'' format • balanced coverage of planets and stars • latest front-line research • enrichment essays, including material on pseudoscience (such as astrology and UFO's), telescopes and observing, etc. • glossary • references • end-of-chapter problems and projects

Publication Date: February 1978.
Casebound. 8⅜ x 9¼. 544 pages.

William K. Hartmann (Ph.D., Astronomy, University of Arizona) is a senior scientist at the Planetary Science Institute in Tucson, Arizona. In addition to his writing, he has participated in NASA planetary explorations and is currently studying origins of planetary systems and the evolution of dusty material around the sun and other stars.

Don't miss ASTRONOMY: THE COSMIC JOURNEY—a fascinating exploration of the cosmos by this talented author/researcher!

TO:
WADSWORTH
PUBLISHING COMPANY
Marketing Department
Ten Davis Drive
Belmont CA 94002

☐ Please send me a copy of William K. Hartmann's ASTRONOMY: THE COSMIC JOURNEY for which I have enclosed a check/money order for $16.95.

Or charge my ☐ BankAmericard
☐ Mastercharge

Card # ____________
Expiration Date ____________

(Residents of Cal, Ken, Mass, Mich, NJ, NY, please pay appropriate sales tax.) Handling and postage costs paid by publisher on prepaid orders.

NAME ____________
ADDRESS ____________
CITY ____________
STATE ____________ ZIP ____________

BOX A-JA8

ASTRONOMY

The World's Most Beautiful Astronomy Magazine

Vol. 6, No. 1
January 1978

Established August 1973 by Stephen A. Walther

EDITORIAL
Managing Editor
Penny Oldenburger

Editor
Richard Berry

Associate Editor
Henry J. Phillips

Staff Writer and
Astro-News Editor
Mary Jane Lamers

Contributing Editors
James Mullaney
James E. Oberg

Contributing Photographers
Bob Provin
Brad Wallis

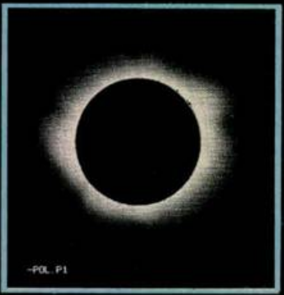
GRAPHICS
Production Manager
David A. Schwartz

Staff Artist
Mark Paternostro

CIRCULATION
Subscriber Relations
Jodi Groth
Rosemary L. Pickart

COMMUNICATION
Information Officer
Penny Oldenburger

6 OUR SUN
by Jay M. Pasachoff
25 GUIDE TO BACK ISSUES
26 SKY ALMANAC
Mars at Its Best
28 PLANET FINDER - JANUARY 1978
36 PHOTOGRAPHY IN ASTRONOMY
Photographing the Sun in H-Alpha
by Edwin Hirsch
42 GAZER'S GAZETTE
Observing Herschel Objects
by James Mullaney
50 EQUIPMENT ATLAS
Building A 6" Reflector
Part 5: Two Mountings You Can Build at Home
by Richard Berry
60 ASTRO-MART
65 ASTRO-NEWS
68 MANAGING EDITOR'S MEMO
73 JANUARY STAR DOME
by James Mullaney and Henry J. Phillips
73 Close-Up on the Orion Region



COVER

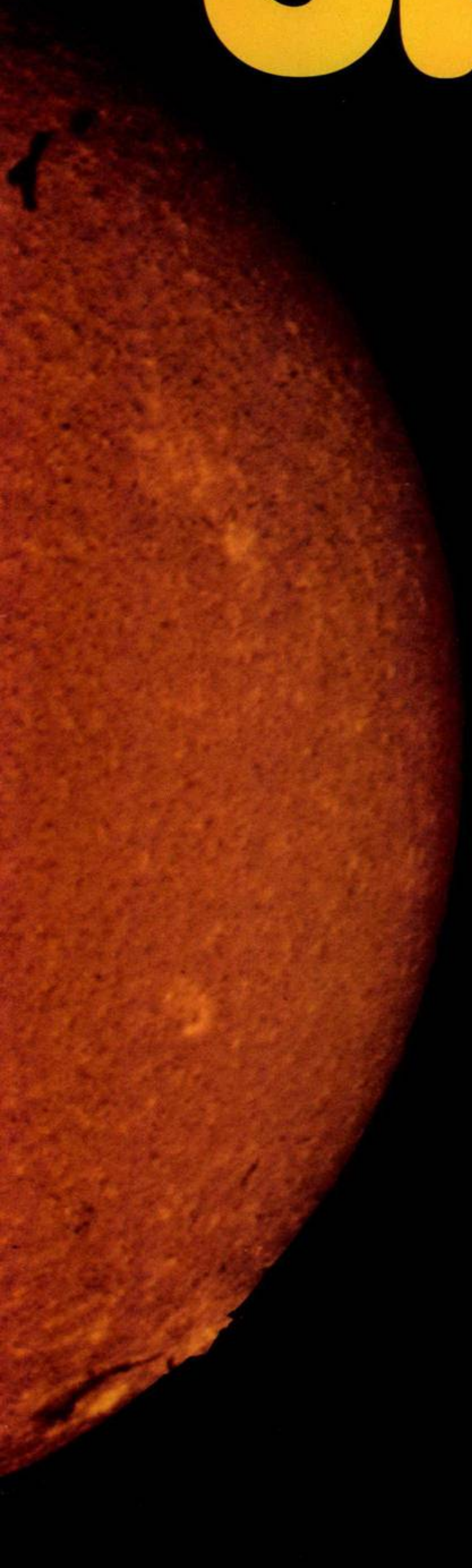
This issue of ASTRONOMY features our sun. The cover shows a computer display of the solar corona of March 7, 1970, made from photographs taken with polarizing filters. Color corresponds to the direction of polarization, and shows, in fact, that the direction of coronal polarization is radial to the sun — that is, always pointed outward. The fact that the corona is polarized tells astronomers that part of the corona's light is reflected from electrons in the corona, which in turn tells much about the actual conditions in the corona. This month's Sky Almanac and Photography in Astronomy are also solar oriented; you'll read about the October 1977 solar eclipse, and see how to make your own solar pictures. Photograph courtesy of Jay Pasachoff and Donald Menzel; computer processing by Lynn Quam and Robert Tucker of Stanford Artificial Intelligence Laboratory.

Published monthly by AstroMedia Corp., 411 E. Mason St., 6th Floor, Milwaukee, WI 53202. Copyright 1977 by AstroMedia Corp., all rights reserved. No part of this issue may be reproduced by any mechanical, photographic or electronic process, or otherwise copied for public or private use without written permission of the publisher. Second class postage paid at Milwaukee, WI. POSTMASTER: When undeliverable, send form 3579 to publisher. Direct all new subscriptions, changes of address, renewals and subscription bill payments only to ASTRONOMY, Circulation Services, P.O. Box 186, Westchester, IL 60153 and allow six to eight weeks for new subscriptions and changes of address to take effect. To speed service on subscription correspondence, complaints, photographs, slides, manuscripts and editorial correspondence write ASTRONOMY, 411 E. Mason St., 6th Floor, Milwaukee, WI 53202. Telephone (414) 276-2689. Due to the limited availability of back issues, new subscriptions must start with the most current month's issue. Cover price, $1.50. Subscription price: 1 year, $12.00. Canada & Mexico: add $3.00 per year. All other foreign: add $6.00 per year. Additional office staff: William Stanfield, Production Assistant; Katherine King, Editorial Assistant; Judy O'Dair, Editorial Secretary; Stephanie Kiel, Administrative Assistant; Nancy Faustmann, Executive Secretary and Bulk Copy Sales; Bruce Precourt, Mail Room Supervisor. Accountant: Peter Trabbold. Consulting Editors: Thomas C. Bretl, John Harmon. Contributing Artists: John W. Clark, Victor Costanzo, Adolf Schaller. AstroMedia Corp. officers: Robert Maas, President; Penny Oldenburger, Vice President. Typesetting by Grafilm, Inc., Milwaukee, WI 53210 and Ries Printing Co., Inc., Butler, WI 53007. Production photography by Communi-Graphics, Milwaukee, WI 53211. Separations prepared by Colorcraft, Inc., Milwaukee, WI 53216. Printed by E.F. Schmidt Co., Menomonee Falls, WI 53051.

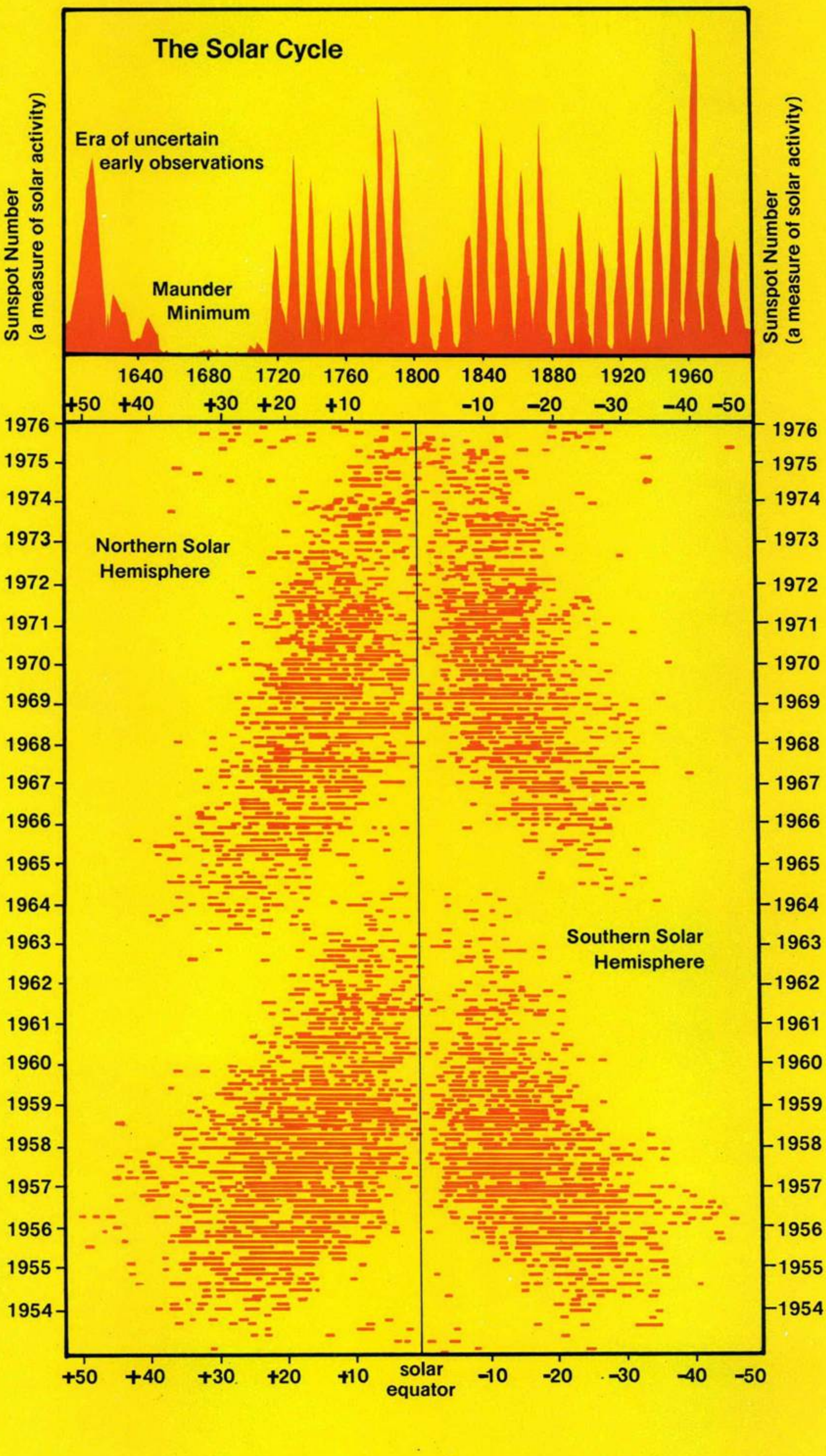
OUR SUN

by

Jay M. Pasachoff



The sun presents a violent ever-changing scene, a complex of events that humans only partially understand! Here, the central sunspot is surrounded by bright plages; long dark lines are solar prominences seen silhouetted against the solar disk. This picture is not how the sun looks to your eye; it has been made in the light of one kind of atom (hydrogen) and shows the temperature and motions of that one element alone. Photograph courtesy of Sacramento Peak Observatory, Association of Universities for Research in Astronomy, Inc.


The Solar Cycle
Sunspot Number (a measure of solar activity)
Era of uncertain early observations
Maunder Minimum
1640
1680
1720
1760
1800
1840
1880
1920
1960
+50
+40
+30
+20
+10
-10
-20
-30
-40
-50
1976
1975
1974
1973
1972
1971
1970
1969
1968
1967
1966
1965
1964
1963
1962
1961
1960
1959
1958
1957
1956
1955
1954
Northern Solar Hemisphere
Southern Solar Hemisphere
solar equator

Ever since Galileo saw sunspots with his new telescope and interpreted them as a sign that the universe was not unchanging, astronomers have continued to find evidence of constant and dynamic activity — both calm and violent — on the sun. And recent solar studies made from space satellites — including Skylab and the Orbiting Solar Observatory satellites — continue to reveal new and violent solar outbursts.

Humans are interested in the sun for at least four major reasons: 1) We are curious about the sun itself, including all the details of its surface and activity — just as we might want to know about the family who lives next door. 2) The sun is a stepping stone to other stars, and phenomena that occur on our sun may work on other stars as well. We can generalize conclusions about the sun to the other stars in our galaxy and the universe beyond. 3) The processes that govern the sun, its generation of energy and the motions of its gases, are often processes that we'd like to understand and utilize on Earth. For example, the beautiful forms we see in the solar corona or in solar flares represent gas constrained by magnetic fields. Our present inability to reproduce these magnetic "bottles" on Earth is a major barrier to understanding how to tap the type of nuclear fusion that fuels the sun and stars. These pollution-free processes — still many years away — could supply Earth and its inhabitants with plentiful energy. Furthermore, the solar energy reaching Earth every day as sunlight may solve our immediate energy needs — and we don't really have to understand *how* the sun generates this energy in order to use it on Earth. 4) The activity and overall brightness of the sun has definite effects on Earth, its climate and weather. Whether or not the 11 year sunspot cycle affects Earth's weather is still controversial, but the overall control of the weather seems unquestionably under the dominance of the sun. Not just the visible output of the sun but also the radio, x-ray, and particle output have their effects on Earth.

Exploring the Sun

Most of the contact humans have had with the sun (and, indeed, with the more distant stars and galaxies) is by radiation. More technically, radiation is known as *electromagnetic radiation* because it results from one of the four fundamental forces of nature — the electromagnetic force, which governs electric and magnetic charges. The other fundamental forces — gravity, the strong force (which holds atomic nuclei together and is also known as the nuclear force), and — to a lesser extent — the weak force (which seems to control only certain decays of nuclear particles) — also play roles in the study and operation of the sun and the other stars.

The Sun: Vital Statistics

Diameter =1,392,000 kilometers
=865,000 miles
=109 Earth diameters
Mass =1.99 x 10^{33} gm
=2 billion billion billion tons
=333,000 Earth masses
Luminosity =3.9 x 10^{33} ergs per second
=conversion to energy of 4,000,000 tons/second of mass
Average density =1.41gm/cm^3
=1.41 times that of water
Surface temperature =5,800 degrees Kelvin
=10,800 degrees Fahrenheit
Central temperature =20,000,000 degrees Kelvin
=36,000,000 degrees Fahrenheit
Most abundant atoms: hydrogen (95 percent)
helium, carbon, nitrogen, oxygen, neon, magnesium (5 percent)
silicon, sulphur, aluminum, calcium, iron and all the rest (0.1 percent)
Age: about 5 billion years
Expected lifetime as a normal star: about 10 billion years

The most familiar form of electromagnetic radiation is ordinary light; other forms of electromagnetic radiation are gamma rays, x-rays, ultraviolet light, infrared rays and radio waves. While different techniques are used by scientists to study these diverse radiations, no fundamental differences exist among them. There are two basic ways to study electromagnetic radiation: One is to look at pictures — *images* — made with it; the other is to break down the radiation into its components — a process known as *spectroscopy*.

Another way in which we're in contact with the sun is through physical particles that slowly flow away from the sun. Known as the *solar wind*, these particles — mainly protons and electrons — envelop Earth as they pass by. Other subnuclear particles, neutrinos in particular, are generated by nuclear processes deep in the sun.

Particle emissions are very important in modern solar studies. Some atomic nuclei are accelerated to tremendous velocities in solar flares, and can strike Earth's upper atmosphere. Studies of particles are also important, because though most of the high energy particles called cosmic rays come

Top: The sunspot count has varied with an approximately regular 11 year period since about 1715 — but for roughly 90 years before that date there were very few or no sunspots visible on the sun. Based on figures by Schneider and Mass published in *Science*. Bottom: The Butterfly diagram plot shows the solar latitude of each sunspot or sunspot group against the date it appeared on the sun. A new sunspot cycle begins with its spots at high latitudes, and ends with its spots occurring at low latitudes. Note that there is a wide spread in sunspot latitudes. Based on a diagram courtesy of Dr. Robert Howard, Hale Observatories.

from beyond the solar system, the paths they travel are affected by the sun and its control (via the solar wind) of interplanetary space.

A final way to study the sun is to send probes directly into it. Since the launch of Sputnik in 1957, satellites in orbit around Earth have been telling us about the solar domination of interplanetary space. More recently, probes sent in closer and closer to the sun have sampled the interplanetary gas directly.

Sunspots and the Solar Cycle

You normally can't look directly at the sun without severely damaging your eyes. But occasionally the sun's brightness is drastically reduced — sometimes at sunrise or sunset, for example, and sometimes on a hazy day. At times like these (and for thousands of years), keen eyed observers have reported seeing dark spots on the sun. When Galileo began his telescopic investigation in 1610, it soon became clear that the spots were actually *on the sun*. The knowledge that the sun was "blemished" — and thus not the "perfect" body it had been thought to be under Aristotelian and Ptolemaic systems — led Galileo to accept the Copernican view that Earth was not at the center of the universe.

Sunspots have been studied for hundreds of years. With each sunspot discovery — even as recently as the early 18th century — scientists of the era wrote scientific papers. By the mid-19th century, astronomers had noticed and published reports that the number of sunspots rises and falls with a period of about 11 years. This period is called the *sunspot cycle*.

In the early 20th century, the superintendent of the solar division of the Royal Greenwich Observatory in London, E. Walter Maunder, plotted the appearance of sunspots on the solar disk against their latitude on the sun. (We can easily imagine the solar surface described by latitude and longitude similar to latitude and longitude on Earth.) Early in each cycle, sunspots appeared at midsolar latitudes, but later they appeared nearer the solar equator. An up-to-date version of Maunder's diagram (known as *Maunder's Butterfly diagram*) is shown on page 8 . On it, we can see some equatorial spots from the old cycle that is currently fading out, while some spots from the new cycle have begun to appear at high latitudes.

The clue to the cause of sunspots stems from a discovery (by astronomer George Ellery Hale) that sunspots are regions with exceptionally strong magnetic fields, some 3,000 times more intense than the average magnetic field of our sun. Strong magnetic fields can restrain hot gaseous matter from flowing across them. Because material in the dark central region of a sunspot (called the *umbra*) is restrained by the magnetic field, it remains somewhat cooler than the rest of the solar surface. The umbra of a sunspot might be 5,400 degrees Fahrenheit (3,500 degrees Kelvin), for example, instead of the 11,000 degrees Fahrenheit (6,000 degrees Kelvin) of the rest of the solar surface. Since it's cooler, it doesn't give off as much light as its surroundings. But if we actually had a sunspot out in the nighttime sky by itself, it might outshine the moon!

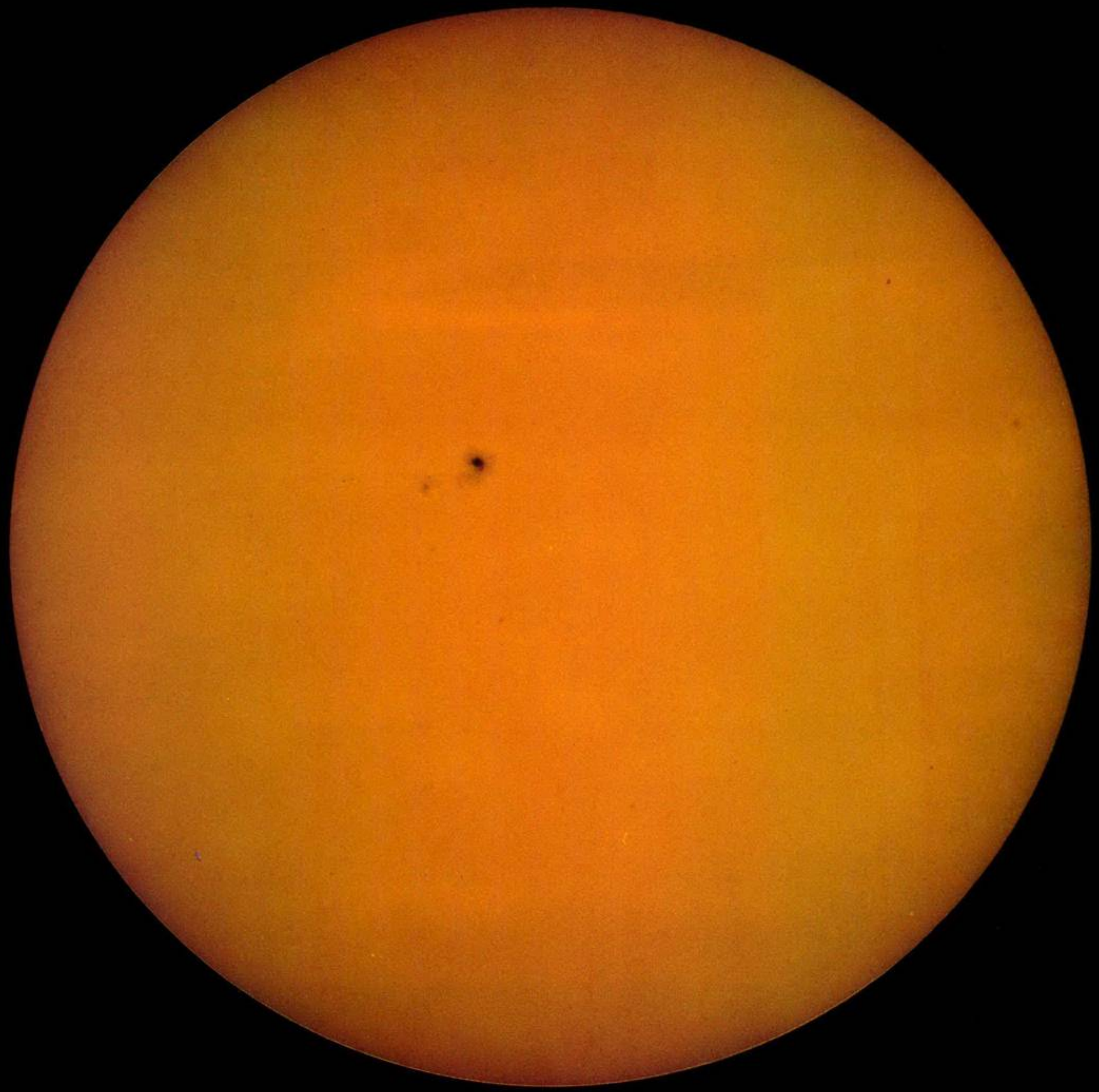
Astronomers can now map the solar magnetic field. At Mount Wilson, Kitt Peak, and other observatories around the world, maps are made every day showing the magnetic field. Magnetic maps can be compared to photographs showing the sunspots, but the magnetic field maps really provide exciting information. The entire region around a sunspot is a disturbed area, called a *solar active region*. Modern solar astronomers consider that solar active regions are basic structures, and that sunspots are merely a symptom of the disturbances.

Solar active regions erupt in giant explosions called *flares*, releasing enormous amounts of activity in a few seconds. The energy released by a flare seems to have been trapped and stored by the solar magnetic field in some way that solar physicists don't yet understand. Flares, as well as other kinds of solar activity, follow the same 11 year cycle that sunspots do. This *solar activity cycle* is next expected to peak in 1980 or 1981, so NASA has scheduled a very important scientific spacecraft called the Solar Maximum Mission to coincide with it.

The solar activity cycle isn't quite as simple as it seems. With each 11 year cycle, the sun reverses the polarity of its magnetic field! The coming 1980

Our sun is, if anything, an ordinary star! Its mass is strictly "middle-of-the-road": the most massive stars are 40 times heavier than our sun, and the smallest 1/50 or so of its mass. Three or four times bigger than a normal dwarf star, and 1/10 the size of a massive normal star, it's rather "run-of-the-mill". It's 100 times bigger than a white dwarf (its ultimate fate when it exhausts its fuel), and 1/100 the size of a red giant (a phase it will pass through late in its lifetime). It's pretty bright — some 10,000 times brighter than the dimmest stars — but it's no showpiece compared to the brightest which are 10,000 times brighter! While the coolest stars are a ruddy dull 5,000 degrees Fahrenheit (3,000 degrees Kelvin) and the hottest a burning blue-white 45,000 degrees Fahrenheit (25,000 degrees Kelvin), our sun, with a surface temperature of 12,000 degrees Fahrenheit (6,000 degrees Kelvin), warms Earth just right for us.

Among the local stars, the sun stands out. There are far more small, faint, low mass stars in a random sampling than there are big, bright heavy ones; the sun thus outshines most of its neighbors. But if we could retreat a few hundred or a thousand light-years, our small dim sun would be swallowed up and lost among the hoards of other normal stars, and our view dominated by a few of the spectacular — but rare — bright stars.



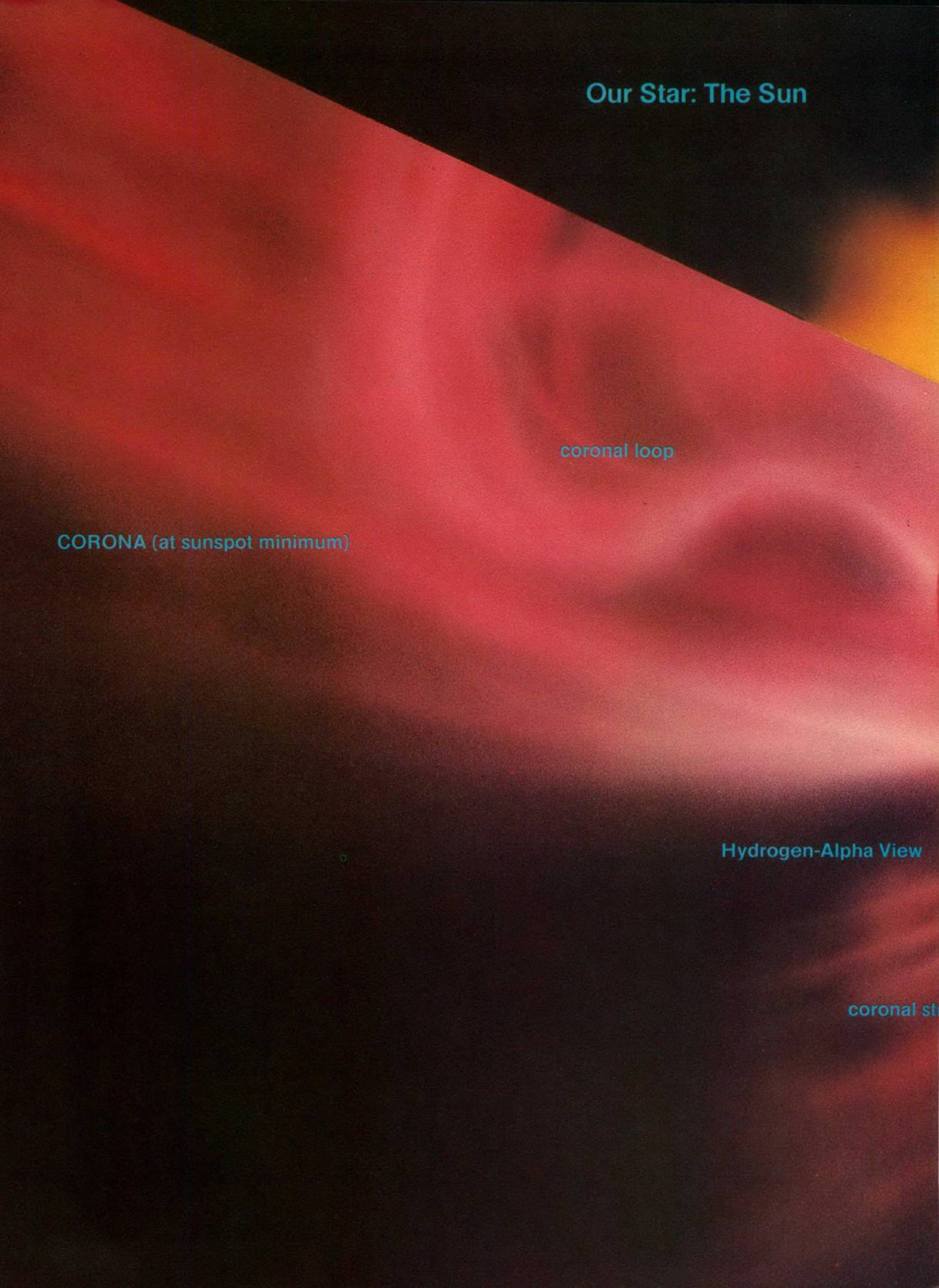
In "white light", the dramatic swirls and streams of roiling hydrogen are not visible because they are overwhelmed by light from lower levels in the solar atmosphere. Nearly central on the solar disk is a medium sized sunspot group, dominated by one giant spot. In this photo taken June 25, 1977, the dark umbra and grayish penumbra are both clearly visible. Near the limb of the sun, a region of plage which is lighter than the surrounding region envelops a small spot. Photograph by James R. Felbab.

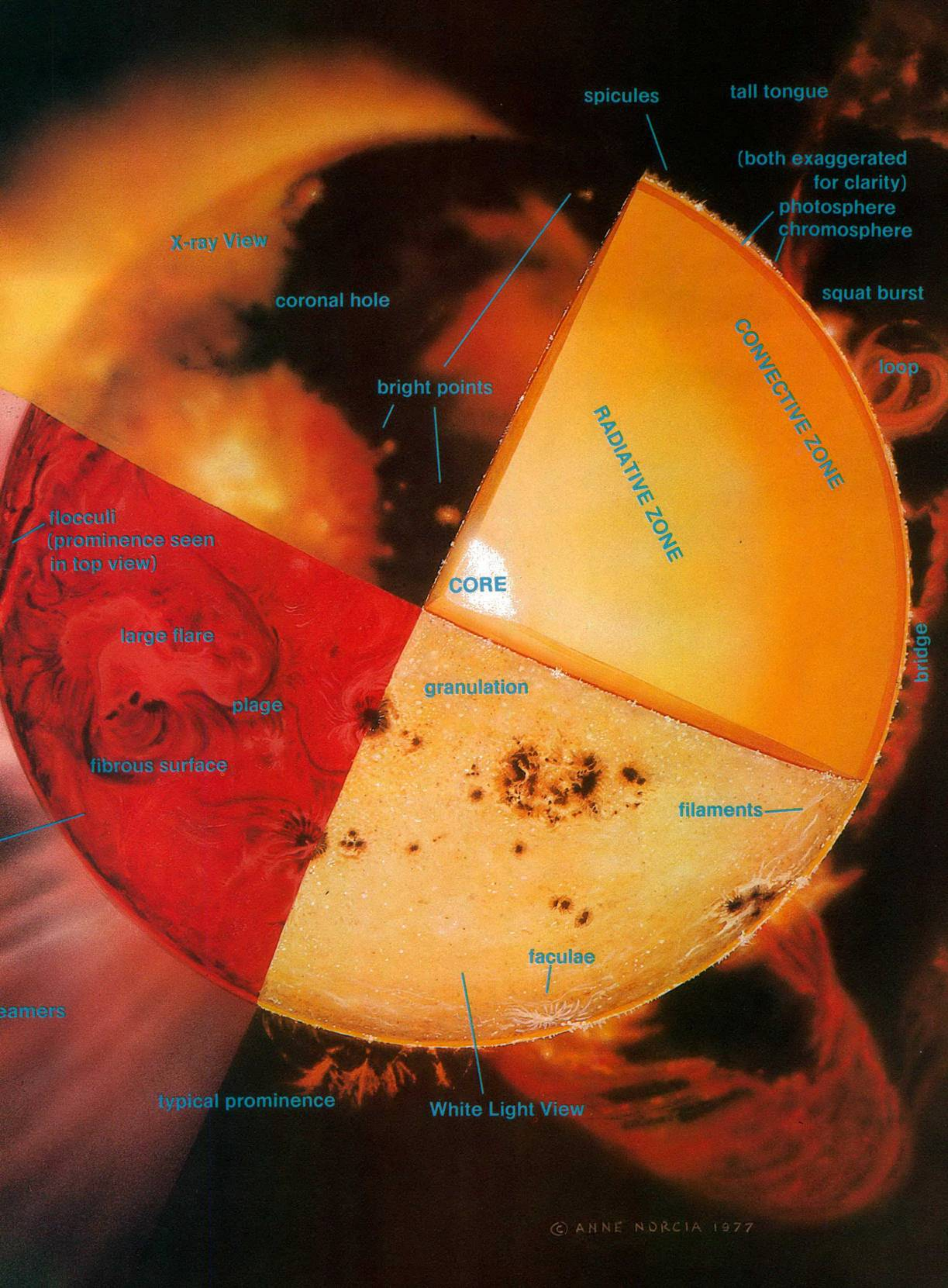
maximum will therefore not correspond to the last maximum in 1969, but to the one before that in 1957-8. Thus the solar activity cycle is really an average of 22 years long.

Has the solar cycle always been there on the sun? Maunder commented that there seemed to have been a period between about 1645 and 1715 when there were few or no sunspots on the sun. This statement seems to have been forgotten until recently when John A. Eddy (then of the High Altitude Observatory and now also the Harvard-Smithsonian Center for Astrophysics) began studying this interesting sunspot free period on the sun. He checked records of other phenomena that correlate with sunspot activity — such as the presence of aurora borealis — and discovered that aurorae were nearly absent during the time when sunspots were rare. The 17th and 18th century astronomers were not merely lazy; we know that their interest in sunspots was such that, if the spots had been present, their appearance would have been reported. There really seems to have been a drop in solar activity from about 1645 to 1715 (a period that Eddy refers to as the *Maunder minimum*).

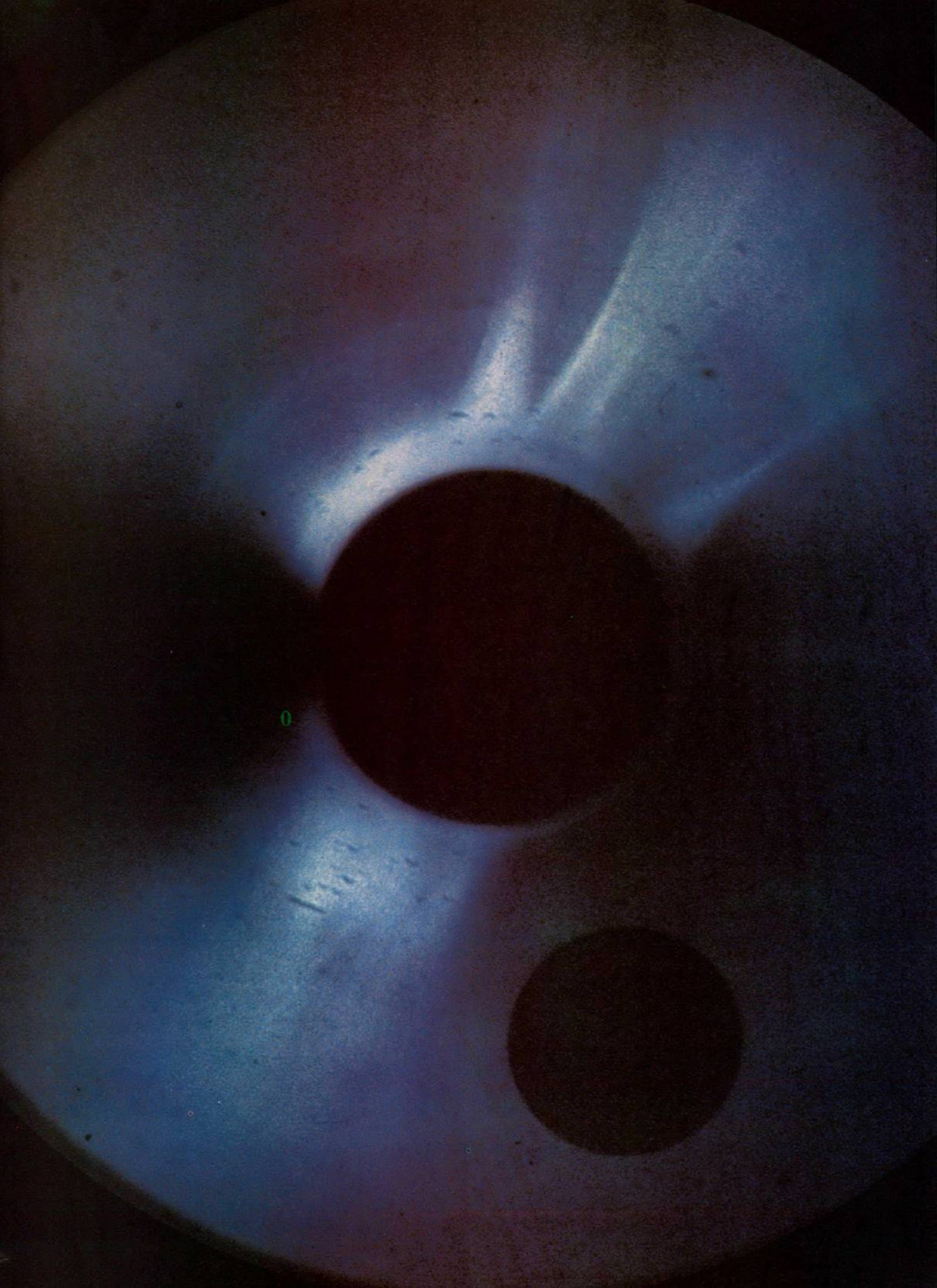
The Maunder minimum coincides with an extremely cold period in Europe known as the "Little

Our Star: The Sun


coronal loop
CORONA (at sunspot minimum)
Hydrogen-Alpha View
coronal st


spicules
tall tongue
(both exaggerated
for clarity)
photosphere
chromosphere
X-ray View
coronal hole
squat burst
CONVECTIVE ZONE
loop
bright points
RADIATIVE ZONE
flocculi
(prominence seen
in top view)
CORE
large flare
bridge
granulation
plage
fibrous surface
filaments
faculae
eamers
typical prominence
White Light View

© ANNE NORCIA 1977



Ice Age". Eddy, in reviewing older historical records for similar correlation, found that long term variations in the solar activity cycle may well have caused other important modifications in Earth's weather. If the sunspot cycle can shut itself off for 70 years, then it is clearly not as permanent a part of the sun as we had thought.

The Quiet Sun

Sunspots and solar activity are part of what astronomers call the *active sun*. We'll examine solar activity later, but first let's discuss the sun's everyday, nonchanging structure — the aspect of the solar atmosphere we call the *quiet sun*.

The surface of the sun that you see each day — the level of the sun from which we get our light and heat — is the *photosphere* (from the Greek *photos*, meaning light). You're thinking of the photosphere when you picture the sun rising in the morning and journeying across the sky in the course of a day.

The upper levels of the sun cannot normally be seen from Earth, except when the moon blocks off the photosphere at eclipses, or with special instruments astronomers have devised to detect them. Just above the photosphere lies a thin layer called the *chromosphere* (from *chromos*, the Greek word for color). It is only about two percent of the solar radius in thickness. When we see it at eclipses it glows pinkish in color. Above the chromosphere is the *corona* (from the Latin word for crown), which forms a faint halo around the sun. When you look at the sun on an ordinary day in "white light" (all the visible part of the solar radiation taken together), the chromosphere and corona are transparent, and you can see the photosphere right through them.

Since the sun is entirely gaseous, there is no sharp line of demarcation that keeps you from seeing in. Rather, as you look into the solar atmosphere, the solar equivalent of fog mounts up. You can see through only so much gas; when the total amount of gas you're looking through increases sufficiently to become opaque, you are seeing the photosphere. Since the photosphere is opaque and radiating brightly, you can't see beyond it, and you can't see anything in front of it because the gas in front is almost transparent, and the photosphere is too bright. Thus all the radiation humans normally see comes from a single, thin layer of the solar atmosphere.

An important way to study the sun depends on breaking the solar radiation down into its component colors in a rainbow display called the *spectrum*. Although Isaac Newton had noticed that a prism could break down sunlight into a spectrum, modern solar spectroscopy began only with the work of Joseph Fraunhofer, a German optician. Fraunhofer noticed that when he observed the spectrum of an isolated strip of sunlight, there were many dark lines crossing the rainbow of color. Fraunhofer, in 1817, labeled the darkest of the lines with the letters of the alphabet — a notation that astronomers and spectroscopists still use today. Thus, you hear about "D lines" in the yellow part of the spectrum resulting from the presence of sodium, and the "H line" from ionized calcium.

This Skylab photograph (taken June 30, 1973) shows coronal streamers stretching millions of miles out from the sun into space. In order to photograph the corona, Skylab astronomers used a special telescope called a coronagraph, which blocks the disk of the sun. From some places on Earth, this was a total solar eclipse. The round dark object in the upper right is our moon, seen in silhouette against the corona. Photograph courtesy of High Altitude Observatory.

Sometime later, it was realized that these dark lines were formed as light from lower levels of the photosphere passed through cooler upper levels en route to us. The cooler upper levels could absorb energy at certain colors, allowing relatively little light at those exact colors to get out. The dark lines are known as *absorption lines* or *Fraunhofer lines*, and are characteristic of the spectra of nearly all stars (see "Between Stars and Space", ASTRONOMY, September 1977).

Early in this century, using the quantum theory, physicists realized that each individual atom could absorb or emit radiation only at certain specific energies, and that each specific energy corresponds to a specific color. If you think of light as being waves, each color has a different distance between peaks called its *wavelength*. All light waves travel at the same speed which, in a vacuum, is called the *speed of light*. It is about equal to 186,000 miles per second (300,000 kilometers per second) — or seven times around Earth in one second!

In fact, astronomers talk about the wavelengths of radiation much more often than they talk of colors as seen by the human eye. To describe wavelengths, they often use Ångstrom units (each being 1/10,000,000,000 meter). All the light that we see with our eye is between about 4,000Å, which we perceive as violet, and 7,000 Å, which we perceive as red. Wavelengths shorter than violet are known as *ultraviolet*; those longer than red are *infrared*.

Visible light is actually just a tiny sliver of the spectrum. The entire visible range, from 4,000 to 7,000 Ångstroms, varies in wavelength by less than a factor of two. The ultraviolet, on the other hand, extends from 4,000 down to about 100 Å (a factor of 40). Shorter wavelengths yet, from 100 down to about 1 Å, are known as *x-rays*, and still shorter wavelengths are called *gamma rays*. The infrared extends from 7,000 Å up to 1mm (a factor of 1,500). Wavelengths longer than 1mm are known as the *radio region* of the spectrum.

All these parts of the spectrum are essentially equivalent, with the wavelength being the only difference. From short to long, gamma rays, x-rays, ultraviolet, visible, infrared and radio waves are merely parts of the *electromagnetic spectrum*. Of course, the fact that wavelengths differ so much means that astronomers use different means to study the different parts of the spectrum. Furthermore, not all wavelengths pass freely through Earth's atmosphere; only the visible, parts of the infrared, and the radio region reach us at Earth's surface. Until recently, when rockets and satellites liberated us from Earth's surface, astronomers could only study a small part of the solar spectrum. The expansion of human senses into new parts of the spectrum led to a revolution in our understanding of the sun.

The Fraunhofer spectrum in visible light tells a lot about conditions in the photosphere. By comparing solar spectra with the spectra of gases in laboratories on Earth, astronomers have identified the elements on the sun. Even more exciting, from the darkness of the spectral absorption lines, solar physicists can tell the relative amounts of each element: The sun is more than 90 percent hydrogen, with most of the rest being helium. All the other elements comprise less than one percent of the solar atoms. Nevertheless, it is these other elements that cause most of the spectral absorption lines.

From a study of the relative strengths of the several different lines that an element may have, astronomers can also tell the temperature of the gas on the sun. If the temperature rises sufficiently, one or more electrons may be torn away from the rest of an atom; the remainder is called an *ion*. The D line of sodium comes from *neutral* sodium (sodium that has its full complement of electrons). The H and K lines of calcium come from *ionized* calcium (calcium that has lost one electron). More precisely, the H and K lines come from *singly ionized* calcium. Atoms in the solar corona, where it's very hot, may have lost five, ten, or even more of their electrons.

The temperature in the solar photosphere is about 11,000 degrees Fahrenheit (6,000 degrees Kelvin), and gradually decreases outward. The temperature may go as low as about 8,000 degrees Fahrenheit (4,200 degrees Kelvin).

The Chromosphere

After the temperature reaches a minimum going out from the photosphere, it begins to rise. The low point corresponds roughly with the lower part of the chromosphere. Average chromospheric matter may be at a temperature of about 25,000 degrees Fahrenheit (15,000 degrees Kelvin). Just how and why the chromosphere is hot is the subject of much current research. Generally, the chromosphere (and corona) heat up because energy is being dumped in them from somewhere below the photosphere. That energy is carried upward in *shock waves* (of which sonic booms from jet planes are a familiar example). However, the details of the processes that bring energy into the sun's chromosphere and corona aren't well understood. Many of the observations made with the latest spacecraft in NASA's series of Orbiting Solar Observatories, OSO-8, were devoted to the study of the heating of the chromosphere.

Studies of the chromosphere often use the *Doppler effect* (which shifts the wavelength of radiation when the body emitting or reflecting the radiation is moving toward or away from us). High resolution studies of the solar spectrum show that individual blobs of gas are moving, thus making the Fraunhofer lines appear wiggly. The up and down motions turn out to be periodic, at intervals of five minutes. At both photospheric and chromospheric levels, these oscillations can lead to the formation of shock waves and are certainly connected with the heating of the chromosphere. The oscillations probably result from motions in the layer of the sun lying just under the photosphere where we cannot see the motions directly.

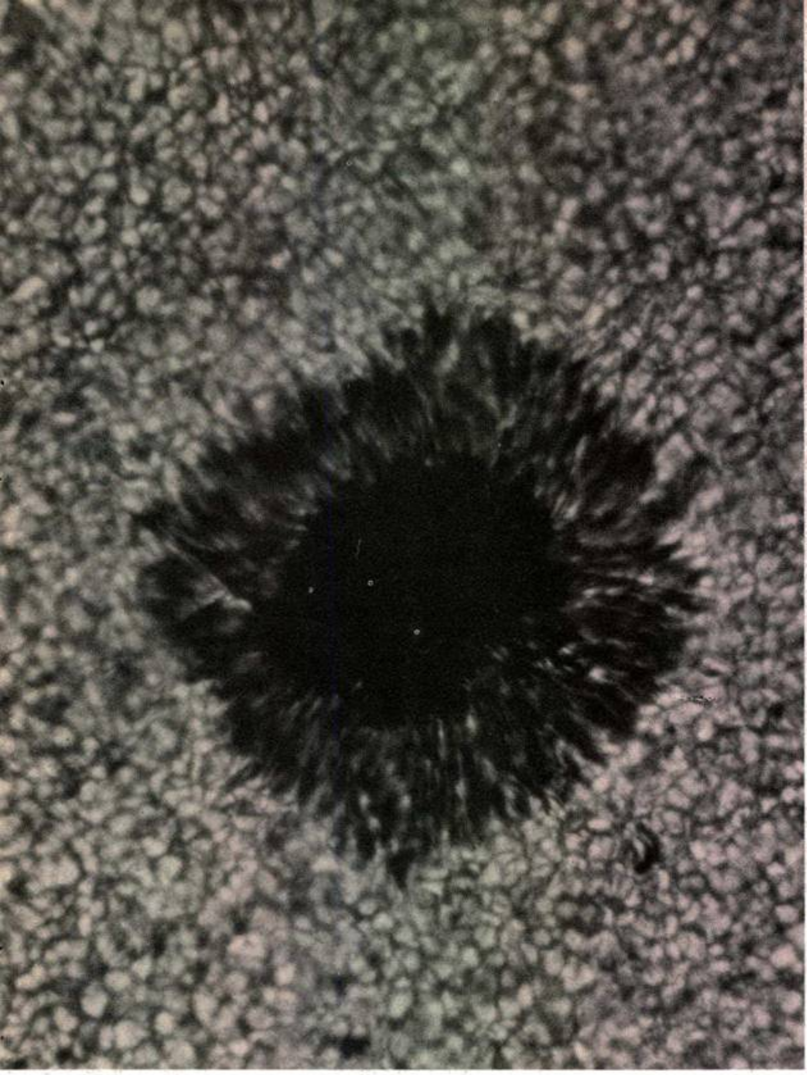
The transfer of energy from below means that the chromosphere is not a smooth layer; it's made up of hundreds of thousands of small jets of gas called *spicules*. A spicule is only about 450 miles (700 kilometers) across, not far in size from the distance from Los Angeles to San Francisco, and is about 10 times as high. Spicules live only about 15 minutes. It's still controversial whether or not there is any material in the chromosphere besides the spicules. Spicules may *be* the chromosphere.

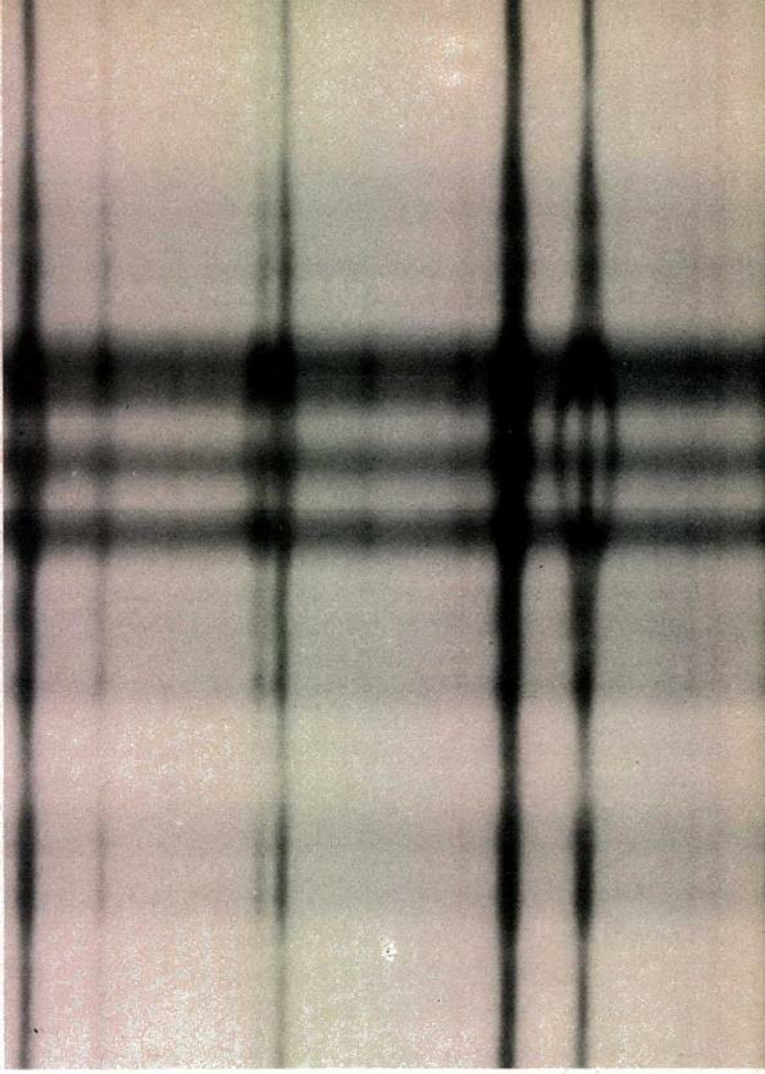
The spectrum of a spicule, and thus the spectrum of the chromosphere, is best seen in the visible part of the spectrum at the edge of the sun. Then the hot gas shines brightly against the dark sky. Spectra made during eclipses don't show the Fraunhofer spectrum typical of the photosphere, but instead reveal just a few bright spectral lines against a dark background. The strongest line is the red line of hydrogen known as H-alpha; also very strong are the ultraviolet lines of ionized calcium. These and a few other bright lines give the chromosphere its colorful appearance.

The Corona

Outside the chromosphere, extending millions of miles into space, is the corona. This pearly white halo of hot gas is visible to the naked eye only during total solar eclipses.

The corona shows many kinds of structures, including long rays called *streamers* that extend radially outward, shorter *loops* nearer the photosphere and chromosphere, and streaks called *plumes* near the poles. These beautiful and delicate structures reveal the shape of the solar magnetic field because the field restrains and therefore "shapes" the coronal gas. Some solar physicists now use maps of the magnetic field in the photosphere to predict the shapes of the coronal magnetic field, and thus how the streamers will appear. Though their success at matching predictions with the actual observations made at eclipses is not total, their





This high resolution image shows a small sunspot typical of the kind that appear near solar minimum — a single spot not part of a complex sunspot group. The dark center is the umbra, and the petal-like gray region is the penumbra. The sun's surface is covered with a granulation pattern of rising and sinking cells of hot gas. Sacramento Peak Observatory photograph. Right: Sunspots are regions of intense magnetic activity. In this high resolution spectrum cutting across a sunspot, spectral lines are split into two or three parts. Astronomers use this effect to measure solar magnetic fields. Kitt Peak National Observatory photograph, copyright © by the Association of Universities for Research in Astronomy, Inc.

ability to make accurate predictions is improving.

Although most observations of the corona have been at eclipses, in the last decade astronomers have been able to make extensive observations from space platforms, including OSO-7 (Orbiting Solar Observatory 7) and the Skylab spacecraft. Coronagraphs — special telescopes designed for observing the corona by blocking out the bright photosphere — aboard these spacecraft have sent back series of observations of the corona that extend over many weeks. Never before could astronomers watch the outer corona change and evolve. The corona is far more dynamic than they had ever expected: Giant eruptions of gas eject coronal material into interplanetary space.

From ground based observatories, astronomers use coronagraphs to observe the innermost corona. The observations are possible only from very special sites at high altitudes located in especially clear and dust free skies. Even at these sites, only some days are good enough to allow coronal observations. The world's coronagraph sites include the University of Hawaii's observatory atop Haleakala Crater on the island of Maui, Sacramento Peak Observatory in New Mexico, Pic du Midi Observatory in France, and Jungfrau Observatory in Switzerland.

The corona can also be studied from the ground with radio telescopes. At radio wavelengths, observations of the corona are a daily routine. Some radio observatories, such as the Air Force's Sagamore Hill Radio Observatory in Hamilton, Mass., do not try to resolve detail in the solar features; instead they concentrate on careful measurements of the intensity of radiation in different parts of the radio spectrum. Other radio observatories use a group of antennas linked together to provide pictures of the sun. One such radio telescope at Culgoora, Australia, is spread over a circle two miles in diameter.

Since the 1930s, solar astronomers have known that the gas in the corona is exceedingly hot — millions of degrees. Astronomers observe that the spectrum of the corona shows that atoms are stripped of many of their electrons — which can only occur at extreme temperatures. Iron, for example, commonly appears in the corona in a form where it has lost half of its normal 26 electrons. The spectrum of the inner corona does not show the Fraunhofer lines that appear in the spectrum of the photosphere, even though some of the coronal light is just light reflected from the photosphere to us by electrons in the corona.

Why does this indicate a high temperature? The Doppler effect causes the light reflected from hot, fast moving electrons to change in wavelength enough to smear the lines until they're invisible. Atoms in the photosphere — at a "mere" 6,000 degrees Kelvin or so — aren't moving fast enough to smear the Fraunhofer lines.

Radio radiation is another sign of the corona's incredibly high temperature. The strength of the radio emission can be used to find the temperature of the radiating gas. The result is a temperature in general agreement with that determined by optical methods.

Satellite observatories can measure the solar spectrum in the far ultraviolet and x-ray part of the spectrum at wavelengths 10 to 1,000 times shorter than the wavelengths of visible light. At these very short wavelengths, the photosphere (which radiates most strongly in the visible part of the spectrum) radiates very weakly. Most of the far ultraviolet and x-ray spectral lines come from the corona. Thus spacecraft can observe the corona every day — without using coronagraphs to hide the sun's disk — by studying it in the ultraviolet and x-ray wavelengths. By studying the distribution of the gas that emits any one of these spectral lines, astronomers now routinely make maps of the corona.

Only 15 years ago, astronomers realized that the corona was continually expanding rapidly into space. The outflow is literally a solar wind of particles (mainly electrons and ions). The solar wind extends far beyond the orbit of Earth; in fact, after the Pioneer 11 spacecraft left Jupiter en route to Saturn, its particle detectors found Jupiter's "shadow" — a region where the giant planet blocks the solar wind.

The particles of the solar wind also affect things in space. For example, the tails of comets can be blown around by the solar wind! The solar wind also pulls the sun's magnetic field into space with it. Its particles interact with the magnetic fields of the planets, also producing aurorae on Earth.

Skylab produced exciting new observations. Scientists noticed that some regions of the corona produce especially weak radiation. In these regions — called *coronal holes* — the density of matter seems to be very low. There are usually coronal holes at both the north and south poles of the sun, and additional coronal holes may appear nestled among coronal streamers at lower solar latitudes.

The solar wind flows especially from the coronal holes. It's long been known that the solar events cause *magnetic storms* in Earth's upper atmosphere. The source on the sun linked to the magnetic storms seems to be the coronal holes.

In the last few years, the United States and West Germany have jointly sent two very successful satellites to sample the solar wind and interplanetary space much closer to the sun than Earth. A variety of other spacecraft are now returning so much data on the solar wind that solar physicists can at least begin to put together three-dimensional pictures of its distribution (see "Probing the Nearest Star", ASTRONOMY, August 1977).

For years astronomers have been puzzled about the origin of *cosmic rays* — nuclear particles that strike Earth's atmosphere at tremendous speed. Cosmic rays behave rather strangely: When the amount of activity on the sun is greatest, there are fewer cosmic rays striking Earth. The explanation is probably connected with the solar wind, which carries with it the solar magnetic field, which in turn blocks cosmic rays. At times of strong solar activity, the blocking is especially effective. Thus the observation that the solar wind becomes weaker and stronger in accord with the solar activity cycle explains why the number of cosmic rays varies in the opposite manner. This inverse variation is known as the *Forbush effect*. Most cosmic rays themselves probably come from distant supernovae. (For more about cosmic rays, see "Gamma Rays and the Origin of Cosmic Radiation," ASTRONOMY, June 1977.)

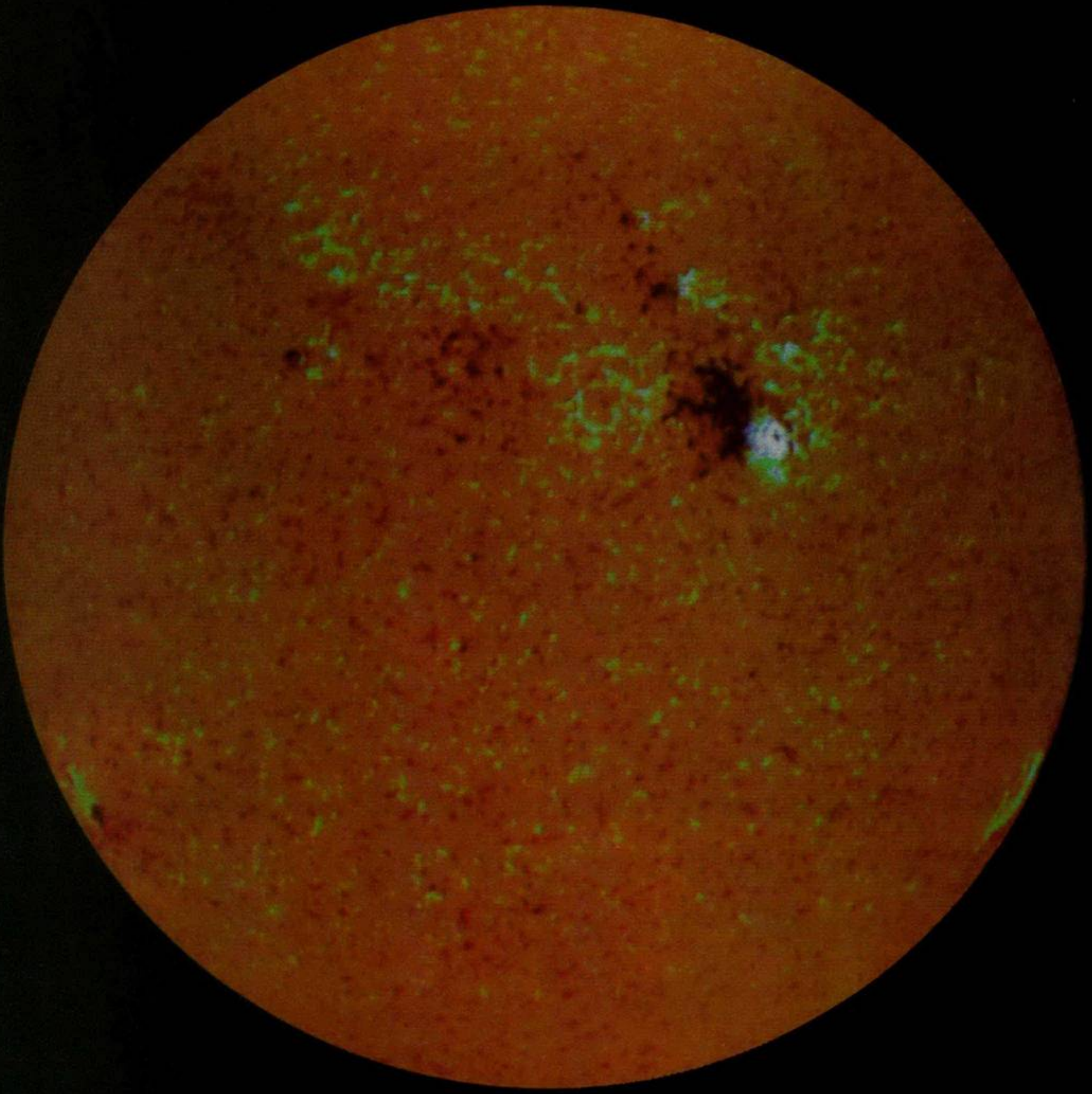
The Active Sun

The most visible signs of solar activity are sunspots, but a whole range of things on the sun vary with the solar activity cycle. The "collection" of these things is known as the *active sun*.

When you observe the sun in white light, sunspots appear dark against the bright photosphere. Using special filters to see in hydrogen light, however (see this month's Photography in Astronomy), the entire region surrounding the sunspot or sunspot group looks relatively bright. This region is called the *plage* (from the French word for beach). Plage areas show up in the light of the strong calcium spectral lines as well; historically, plage areas are sometimes called *faculae* when observed in this way. Especially when observing close to the limb, or edge, of the solar disk, you may see *white light faculae* as well.

Sometimes there are huge violent eruptions — flares — from active regions. In just a few seconds, tremendous amounts of energy are released; gas is hurled into space at high velocities.

Hundreds of flares — some giant and others tiny — occur each year. At the time of maximum solar activity, there are both more and stronger flares. Extremely large flares can be seen in white light, but on the average, only one per year is observable that way. Small flares are usually ob-

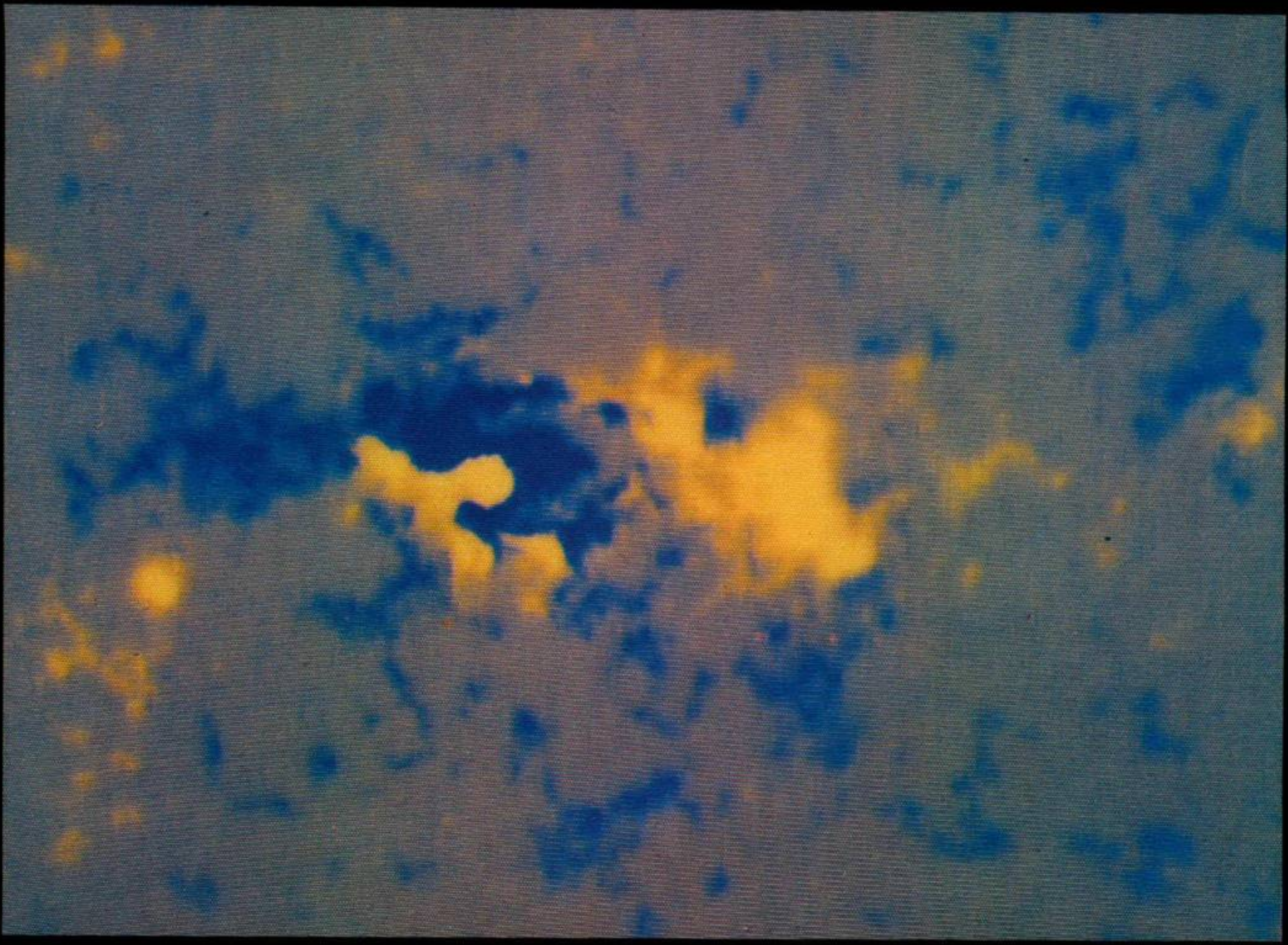


Magnetic fields play an important role in solar activity and the solar cycle. Solar astronomers map the solar magnetic field daily with spectroscopic and electronic instruments, using effects such as the Zeeman effect seen on page 16. In the solar image above, white or green indicates a north magnetic polarity. The yellow regions have a weak field. Compare this picture, taken July 1, 1977, with the pictures on pages 11 and 20 made within a few days. Photograph courtesy of Robert F. Howard, Mount Wilson Observatory.

served in the red light of hydrogen (H-alpha).

One of the best ways to study flares, since astronomers can't predict exactly where or when they'll occur, is to make time-lapse movies. At the Big Bear Solar Observatory in California, for example, every 15 seconds daily, astronomers take pictures of the sun through H-alpha filters in the hope of catching a flare in action. Though it's relatively easy to turn on the cameras when a flare has gone off, it is much harder to make important observations at the beginning of a flare, for seeing the formation of flares will help lead to a theoretical understanding of what is going on. Though many theoretical models have been advanced to explain flares, none is fully accepted. However, all flare theories include the general idea that energy is stored in the solar magnetic field until it can be released all at once in a violent flare.

In a flare, temperatures can reach five million degrees Kelvin, producing huge amounts of x-rays. Observations in the x-ray region of the spectrum made from spacecraft now give solar physicists much of their data about flares. The high temperatures lead to emission of radio waves as well, so solar radio telescopes are among the instruments used to follow the evolution of flares. Comparison of



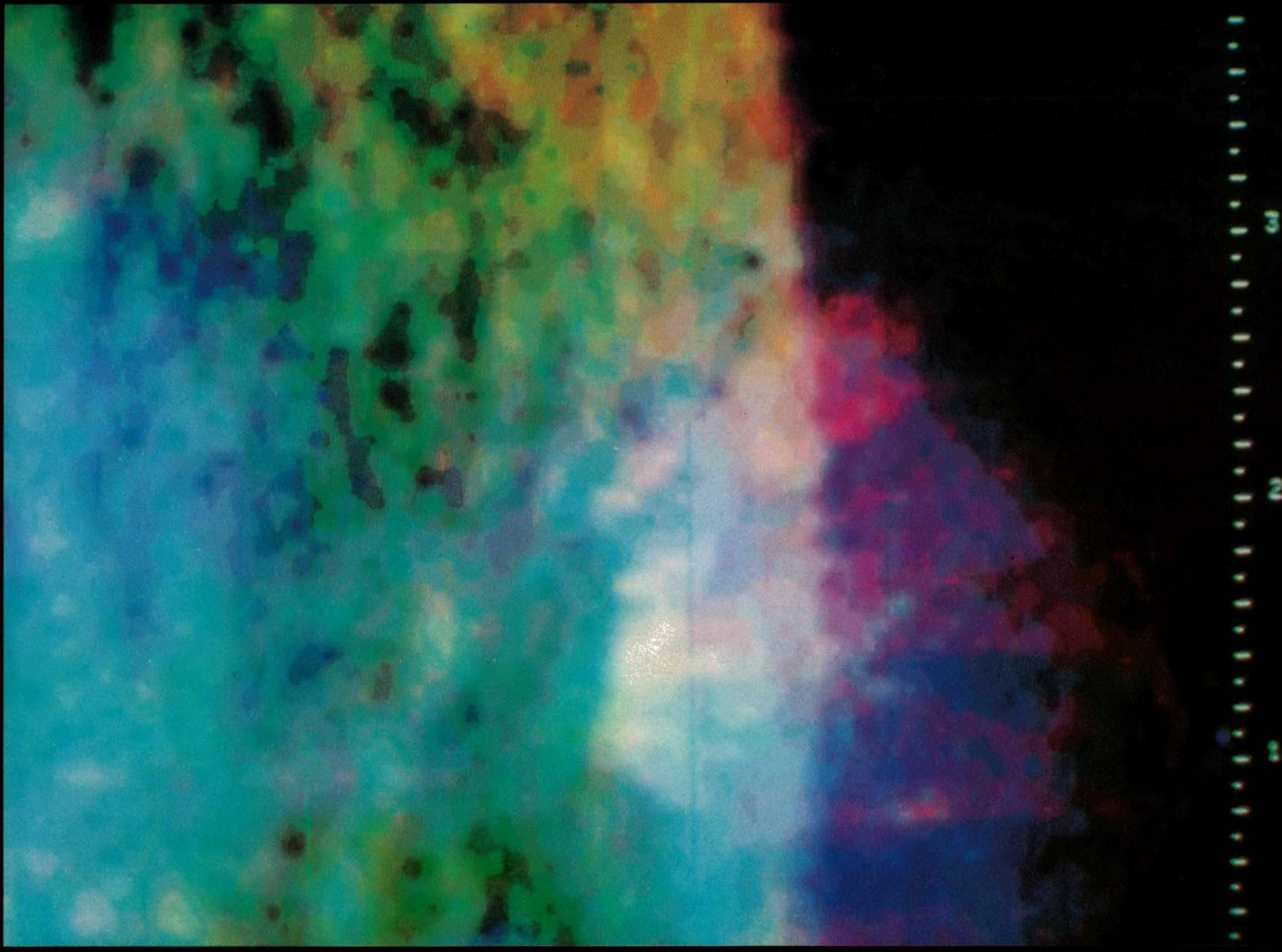
Above: Magnetic fields around sunspots are complex tangled affairs that constrain the motion of the hot gases in and around the spot group. All the active region phenomena — spots, faculae, prominences, flares, and many aspects of the corona — are intimately related to the presence of the magnetic field. Kitt Peak National Observatory photograph, copyright© by the Association of Universities for Research in Astronomy, Inc. Right: A prominence on the limb of the sun was observed by sophisticated instruments aboard Skylab on Sept. 11, 1973. This image is made of three far-ultraviolet wavelength pictures reproduced in visible colors. Green represents the Lyman-alpha line emitted by cool hydrogen gas; red is medium temperature three-times-ionized oxygen gas at 554 Angstroms; blue represents 1 million degrees Kelvin (1.8 million degrees Fahrenheit), nine-times-ionized magnesium. Such images help solar physicists understand the complex interactions of different materials. Harvard College Observatory photograph.

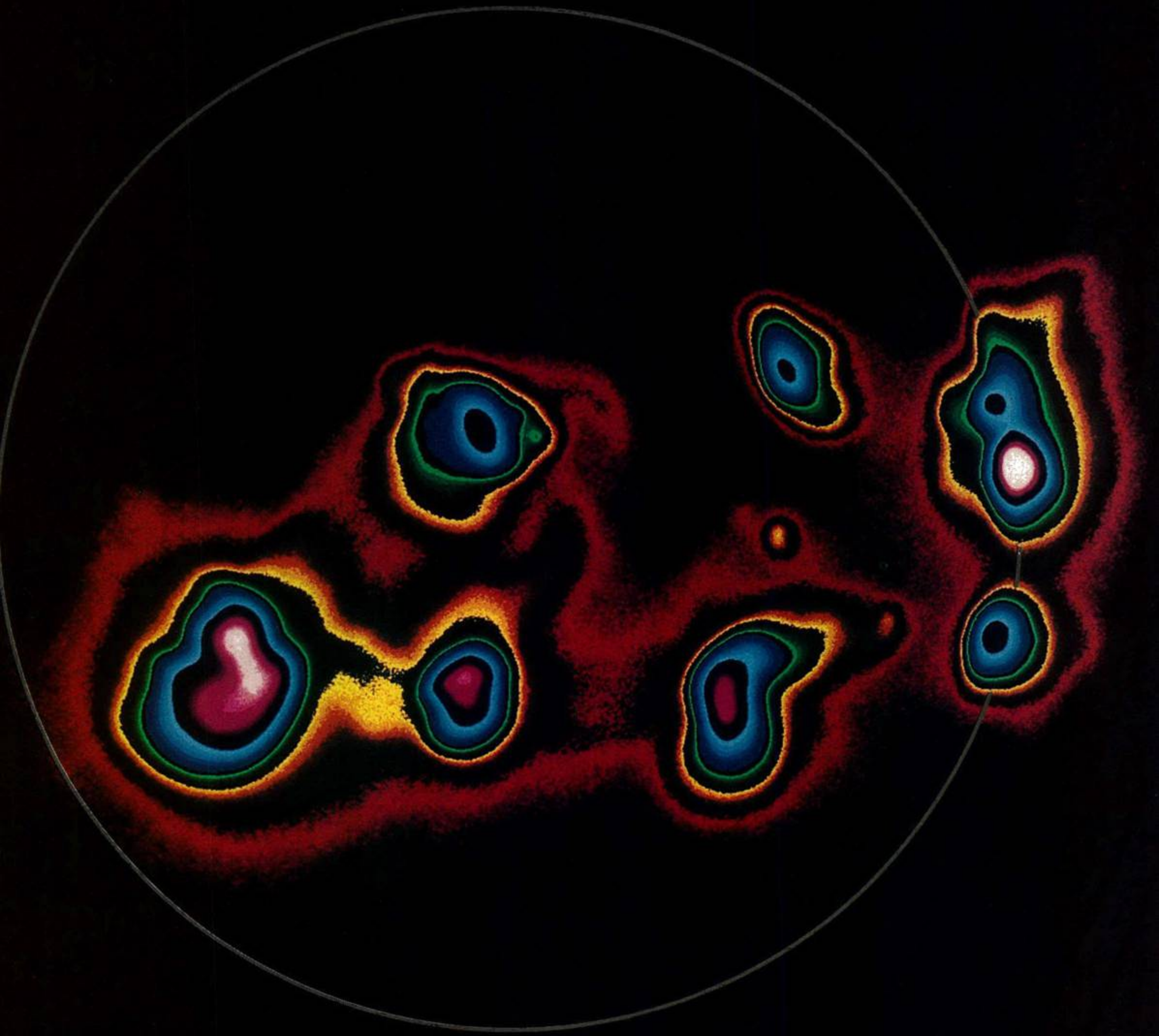
all these flare observations across the spectrum — from x-rays and gamma rays at the short end to radio waves at the long end — will ultimately yield clues that astronomers need to fully understand what flares are and how they occur. X-ray satellite observations of a flare have even revealed a spectral line that may be the fusion of two hydrogen nuclei into a nucleus of deuterium (heavy hydrogen). Hydrogen fusion at the surface of the sun is an indicator of exceedingly high temperatures!

In solar flares, hot gases and large amounts of radiation are ejected from the sun. Flares caused some of the disturbances traveling through the corona detected by Skylab and the OSO satellites. Both the ejected gas and the radiation travel through space to Earth — but the gas takes a few days, while the radiation only takes about eight minutes. When they hit Earth's magnetic field and atmosphere, the effects that result include aurorae, blackouts in radio communications, surges on power lines, and radiation danger to passengers in high flying airplanes and astronauts. So the sun is closely watched; solar "weather reports" and forecasts are made regularly by NOAA (National Oceans and Atmospheres Administration) from their Boulder, Colo. laboratories. The Air Force also has a network of stations that report the solar weather.

Prominences, the pinkish structures seen along the limb during solar eclipses, are also part of the active sun. Since prominences are midway in brightness between the corona and the photosphere, you can see them without excessive difficulty on Earth by using special narrow-band filters passing hydrogen radiation.

Prominences emit strongly in spectral lines such as the red line of hydrogen and the ultraviolet lines of ionized calcium, indicating that prominence temperatures are much closer to temperatures of the chromosphere than they are to those of the corona or flares. Ultraviolet and x-ray spectral lines, observed from spacecraft, reveal the distribution of temperatures in prominences because each line is formed in a region of a different tempera-


3
2
1



ture. Astrophysicists hope that the way temperatures work in prominences will yield the key to how prominences form and change.

Prominences — especially *eruptive prominences* — expand rapidly through the chromosphere and lower corona; in a few hours they travel a half million kilometers! *Quiescent prominences*, on the other hand, last for weeks or months in almost the same place.

Prominences are relatively bright objects when observed at the edge of the sun, with only the sky as background. Silhouetted against the bright photosphere (in the red light of H-alpha), however, they appear dark. In this form, they are called *filaments*. Filaments seem to snake their way between the sunspots in active regions, following lines where the magnetic force is neutral (neither positive nor negative).

The x-ray sun — photographed from Skylab with 6 to 16 Angstrom x-rays — shows several interconnected active regions. The photosphere is quite dark at these wavelengths; what you see here are hot areas in the corona associated with features — such as flares and sunspots — that occur at lower, cooler levels in the sun's atmosphere. The circle is the outline of the visible sun. This shot was taken Sept. 6, 1973 from Skylab. NASA photograph.

Inside the Sun

The solar radiation that we can observe all comes from one level or another of the solar atmosphere. Below the photosphere lies most of the solar mass. In the center of the sun, solar energy is generated via nuclear reactions. This entire unseen region is called simply the *solar interior*.

The solar core, in the center of the sun, is incredibly hot; its temperature probably reaches 27 million degrees Fahrenheit (15 million degrees Kelvin). Both the temperature and density are so high, that atomic nuclei come close enough together that the natural tendency to repel each other is overcome. The nuclei can *fuse* into heavier nuclei, releasing the energy that drives the sun.

That nuclear fusion supplies the energy for the sun — as well as other stars — to shine became generally accepted in the 1920s, although it was not until the late 1930s that the particular schemes by which fusion takes place were worked out. The basic reaction scheme for the sun is the *proton-proton chain*: four hydrogen atoms fuse with each other, one at a time, until a helium atom results. The resulting helium atom has a mass that is slightly less (a mere 0.7 percent) than the mass of the four hydrogen atoms that formed it. This missing mass is converted into energy in the form of radiation. How much energy results? The formula that Albert Einstein advanced as part of his special theory of relativity, $E=mc^2$, gives us the answer. Since c, the speed of light, is such a large number, even the tiny mass lost, when multiplied by the speed of light squared, provides a large amount of energy. A star the mass of the sun, transforming hydrogen into helium at the present rate, should take about 10 billion years in this stage of its life. The sun has already been around for about half its lifetime, and has another five billion or so years left of its post-hydrogen-burning "middle age".

In about five billion years, the sun will have used up most of the hydrogen in its interior. In the center, pressure from nuclear fusion will no longer support it against the force of gravity, so it will begin to contract. In contracting, the inside will become hotter than it has been, thus increasing the radiation output of the core. As a result, the outer layers of the sun will expand. The bloated, future sun will become a red giant. Its photosphere may be as far out as the orbit of Earth, and life on Earth would be seared and destroyed.

Still farther in the future, the helium in the core will begin to fuse into carbon. The sun, its core shrunk and its outer layers expanded in the red giant stage, will keep expanding. Eventually the outer layers will blow off completely, making the sun a planetary nebula. The central regions of the sun will soon shrink into a compact, dense object called a white dwarf. Each teaspoonful will weigh five tons, because the sun will be about the size of Earth! Nuclear reactions will flicker out at this stage, and the sun will be a dead star. As it cools and cools until infinity, it will become fainter and redder.

This scenario has been worked out from observations of many stars of all types — including red giants and white dwarfs that astronomers now observe — mixed with a healthy infusion of theoretical calculation. Obviously, solar physicists and astronomers would like to check their theories with some particular observation, but it's difficult to observe a stellar interior directly. One hope is to measure the rate at which *neutrinos* come from the sun. Neutrinos are subatomic particles with strange properties (compared to protons or electrons). Neutrinos always travel at the speed of light, for example, so they reach Earth eight minutes after leaving the sun. The property most important for an experiment is that they do, in fact, escape the interior of the sun at all! Neutrinos tend not to interact with other matter, so once they're formed in nuclear reactions inside the sun, they escape immediately. To neutrinos, the sun is essentially transparent!

This advantage — that they escape from the sun so easily — is also a disadvantage, because they are hard to detect on Earth. But that disadvantage has been overcome: The strangest telescope in the world is set up deep in a gold mine in South Dakota to study solar neutrinos. On the rare occasions that neutrinos do interact with one type of chlorine atom, they can transform them into radioactive argon atoms, and scientists can measure the resulting radioactivity. Scientists then work back to determine how many neutrinos hit chlorine atoms, and from that how many neutrinos leave the sun each second.

To provide enough chlorine atoms in one place, a 100,000 gallon tank is filled with perchloroethelene (a molecule with two chlorine atoms and four carbon atoms bound together). About 1/4 the chlorine atoms are in the form (the isotope Cl-37) that can interact with neutrinos to form argon. In order that other particles cannot hit the tank, it is located deep underground.

Even with such a large quantity of matter, when the experiment started, only about one interaction per day was expected. Still, the experimental technique was sufficiently developed that this low rate should have been detectable. Results from the experiment are a source of consternation: A very low rate of interactions has been detected — only about 1/4 the rate that would be expected for the proton-proton chain. Other possible schemes for fusion, such as the carbon cycle, predict even higher rates, so the limits placed on them are even more severe.

The problem is still unsolved. Theoreticians have looked closely at their calculations. Methods of making theoretical models of the sun have been improved in an attempt to provide a more realistic picture that might explain the results of the neutrino experiment. But the best predictions are still too high.

The possible solutions to this scientific dilemma suppose the idea that astronomers' models of stellar interiors are not as good as they had hoped. If, for example, the inside of the sun were mixing cooler gas with the hottest gas in the center, then the center of the sun would be cooler than presently thought — and would thus be emitting fewer neutrinos, resolving the dilemma. Alternatively, if the abundances of the elements in the solar interior are different than presently thought, the calculations could be off.

Another interesting possibility is that the sun is not the unchanging lump of gas that we had thought. Could it be a variable star deep inside? Is it actually now in a quiet phase in which it emits few neutrinos? It takes 10 million years for the energy generated inside the sun to reach the surface, while the neutrinos get out in eight minutes. We *could* be observing the solar core *now* when we study neutrinos and, when we study visible light, as it was many years ago. This could conceivably even be linked with the climatic changes that have taken place on Earth.

The main thing that the neutrino experiment is telling astronomers and physicists is that they cannot be too certain that all the details about the solar interior — and the interiors of other stars — are thoroughly understood. The answer may eventually become clear, though it is still unknown.

Energy From the Sun

While humans struggle with the energy supply here on Earth, they need only to look up during the daytime to see a virtually inexhaustible supply of energy: the sun. If we could only capture that energy, our problems would be over.

A variety of devices already exist to capture solar energy directly, and to transform it into a usable form. In some cases, sunlight can be used directly to heat homes or hot water. Simply arranging houses so that solar radiation gets in through windows in winter can save a lot of fuel that would otherwise be used for heating. Gadgets for converting solar energy into electricity exist, though they are not very efficient. The energy converting devices are relatively expensive too, compared with the cost of digging or drilling fossil fuels like oil, gas or coal. Still, when accessibility is a problem (as in ocean buoys), solar energy may be the cheapest solution. Many spacecraft use solar cells to generate their electricity.

In a way, almost all the energy we use is solar energy: Gas, oil and coal are but ancient sunlight locked in the ground. The problem is that our supplies of fossil solar energy will soon be used up. For some parts of the world, tree farming may be a reasonable way of collecting enough sunlight to be self-sufficient. Trees are renewable resources: By planting young trees when you cut down old ones, you can grow new firewood to replace the old.

Solar Energy: How Does It Work?

The sun is mostly hydrogen, and deep in the core, material is very hot — so hot, in fact, that atomic nuclei can collide fast and hard enough to stick together. Helium is built from hydrogen in a three-step process — the proton-proton chain — as follows:

hydrogen + hydrogen → heavy hydrogen + positron + neutrino
Heavy hydrogen + hydrogen → light helium + gamma ray
light helium + light helium → Helium + hydrogen + hydrogen

If we balance the whole reaction, the net result is:

4 hydrogens → helium + energy

The energy liberated results from the fact that the resulting helium nucleus weighs less (by a tiny amount) than the four protons (hydrogen nuclei) that went into forming it, and that missing mass appears as energy.

It's tempting to use the sun not just as a source of energy, but as a model for mankind to follow. The sun is, after all, a nuclear reactor. In it, hydrogen is fused into helium, but it is safely located 90,000,000 miles (150,000,000 kilometers) away from us, in a location where its potentially dangerous effects cannot reach us. The main byproducts of its fusion are simple elements like helium and carbon, which would not bother humanity. Can we emulate the sun on Earth?

It all boils down to building a fusion reactor — quite a different thing from the fission reactors in which uranium or plutonium are broken down, providing energy — and also radioactive wastes. A fusion reactor would be "clean". Unfortunately, we do not presently know how to keep hydrogen "bottled" where the temperature and density are high enough for fusion. Indeed, no container made of any material we know can hold in matter under these conditions. Fusion research today dwells heavily on magnetic fields as a means of holding matter together. But the magnetic fields we produce on Earth are not sufficiently stable to hold matter for very long — they untwist in a tiny fraction of a second, allowing the hydrogen to escape.

The sun provides other examples of matter constrained by magnetic fields (in the chromosphere, prominences, corona, etc.). By studying the sun, we may be able to learn the basic equations that control matter in magnetic fields. Basic studies of the sun may, in the long run, be our salvation in dealing with the mundane matter of keeping warm on Earth.

The sun, then, is our star. It provides us with warmth, heat, beauty, and awesome spectacle, food, and an intellectual challenge. What more could we ask?

Jay M. Pasachoff is director of the Hopkins Observatory at Williams College. His textbook, ***Contemporary Astronomy*** *(W.B. Saunders Co., 1977), is widely used. A concise version,* ***Astronomy Now****, has just been published, and an expanded version,* ***University Astronomy****, is now in press. He is currently writing a book about the sun.*

Guide to Back Issues

What did Apollo find on the moon? Where can I find something about making a telescope? What's the big bang all about? When has ASTRONOMY had articles about black holes? If you have questions like these, ASTRONOMY back issues can help you. More than 50 issues of ASTRONOMY have been published, containing fascinating articles, exciting pictures and helpful observing hints that you may have missed. But you don't have to keep on missing them. While supplies last, you can buy ASTRONOMY back issues at the *original price* — just $1.50 each*. Don't wait another moment to order — when supplies are depleted, there won't be more!!!!

August 1973: FIRST ISSUE. "Hour of the Midday Night" (Solar Eclipses); "In Search of Planet X"

March 1974: "The Cosmic Abyss"; "What Happened to Comet Kohoutek?"; "Magnetic Fields Beyond Earth"

July 1974: "Astronomy From Skylab"; "What Radio Eyes Would See"; "An Introduction to Small Telescopes"

May 1975: "The Search for Intelligence"; "Countdown to 2001" (Future of the Space Program); "Comet Exploration from Space"; "The Realm of the Galaxies"

July 1975: "The Quest for Life on Mars"; "The Age of Nearby Stars"; "An International Space Venture" (Apollo/Soyuz); "Mysteries of the Galactic Core"

August 1975: "Showers of Fire" (Meteors); "Faster Than Light?" (Quasars); "Observing the Perseid Shower"

September 1975: "Baptism of Fire" (Meteor Craters); "The Quasar Dilemma"; "Cosmic Rays"; "Let's Take a Look at the Sun . . . Cautiously"

October 1975: "Aurora"; "Starspots on Betelgeuse"; "Shape of the Milky Way"; "Observing Jovian Detail"

November 1975: "Big Bang to Galaxy"; "Mars' New Frontiers"; "Two X-Ray Stars"; "Find a Comet"

December 1975: "Astronomy From the Moon"; "The Planet Mercury"; "Mars at Opposition"; "Tune Up Your Telescope" (Collimating Optics)

February 1976: "Io"; "Exploding Stars"; "How Far Is Up?" (Stellar Distances); "The Gibbous Moon"

March 1976: "Beyond Space Shuttle"; "Whispers of the Cosmos' Birth" (Cosmic Microwave Background); "Infrared Astronomy"; "Life's Protective Shield" (Magnetic Field Reversal)

April 1976: "Finding Unseen Worlds" (Astrometry); "Dust Clouds and Ice Ages"; "Astrophotography . . . In Spite of Myself"

May 1976: "Quasars: Oddities of Space"; "Cosmic Explosions"; "Comet West"; "Molecules of Life" (Interstellar Molecules); "Choosing B&W Films"

June 1976: "Asteroids"; "Viewing the Full Moon"; "What You Can See Through a Small Refractor"; "Setting Up an Astrodarkroom"

***July 1976:** SPECIAL ISSUE. "The History of American Astronomy"

August 1976: "Venus"; "Viking Orbits Mars"; "Clusters of Galaxy Clusters"; "Exploring the Milky Way, Part 1"; "Red Light Sky Photography"

September 1976: MOON ISSUE. "The Moon's Early History"; "Science on the Moon"; "The Last Quarter Moon"; "Man Looks at Mars"; "Developing B&W Astrofilms"

October 1976: "Radio Interferometry"; "Searching for Mars on Earth"; "Birthplaces of Stars"; "City Astrophotography"

November 1976: "The Space Telescope"; "Mars Pictorial"; "Black Holes, White Holes and Wormholes"; "Doubles, Binaries and Multiple Stars"

December 1976: "The Magellanic Clouds"; "Radar Astronomy"; "Red Giant Stars"; "Printing Your Astrophotographs, Part 1"; "The Messier Catalog"

January 1977: MARS ISSUE. "Viking on Mars: Exciting Results"; "Life on Mars: Ambiguous Results"; "Printing Your Astrophotographs, Part 2"; "Exploring the Milky Way, Part 2"

February 1977: "Uranus and Neptune"; "Pluto"; "Miniblack Holes"; "Observing Saturn"; "Cold Cameras, Part 1"

March 1977: "Phobos and Deimos"; "New Color Photos of Galaxies"; "Duststorms of Mars"; "Cold Cameras, Part 2"

April 1977: "Supernovae!"; "Astronomers in Space, Part 1"; "Printing Your Astro-Photographs, Part 2"; "Building a Six Inch Reflector, Part 1"

May 1977: "The End of Time"; "Can Life Evolve in Elliptical Galaxies?"; "Building a Six Inch Reflector, Part 2"; "Astronomers in Space, Part 2"

June 1977: "Gamma Rays and the Origin of Cosmic Radiation"; "A Second Ringed Planet"; "Beginning With Your Telescope"; "Observing With Binoculars"

July 1977: "The X-Ray Universe"; "What Makes Novae Blow Up?"; "Tracking Asteroids"; "Astrophotography With Telephoto Lenses"

August 1977: "Slow Boat to Centauri" (Interstellar Travel); "Probing the Nearest Star"; "Does the Universe Oscillate?"; "Building a Six Inch Reflector, Part 3"

September 1977: "Stars With Companions"; "Robot Probes"; "Between Stars and Space"; "Building a Six Inch Reflector, Part 4"; "Light Pollution"

October 1977: MARS ISSUE. "The Polar Regions of Mars"; "Martian Climate"; "Rich Clusters of Galaxies"; "Buyers Guide to Small Telescopes"

November 1977: "The Revolution in Astronomy"; "The Southern Sky"

December 1977: "Why Do Planets Have Rings?"; "Tunguska — Collision With a Comet"; "Learning the Constellations, Part 1"; "Printing Your Astrophotographs, Part 4"

$1.50 per copy
***Special July 1976 issue $3.50 per copy**
U.S. — Add $1.00 per order
Canada/Mexico — Add $2.00 per order
All Other Foreign — Add $2.50 per order

Payment must accompany your order.

- ☐ **August 1973**
- ☐ **March 1974**
- ☐ **July 1974**
- ☐ **May 1975**
- ☐ **June 1975**
- ☐ **July 1975**
- ☐ **August 1975**
- ☐ **September 1975**
- ☐ **October 1975**
- ☐ **November 1975**
- ☐ **December 1975**
- ☐ **February 1976**
- ☐ **March 1976**
- ☐ **April 1976**
- ☐ **May 1976**
- ☐ **July 1976**
- ☐ **August 1976**
- ☐ **September 1976**
- ☐ **October 1976**
- ☐ **November 1976**
- ☐ **December 1976**
- ☐ **January 1977**
- ☐ **February 1977**
- ☐ **March 1977**
- ☐ **April 1977**
- ☐ **May 1977**
- ☐ **June 1977**
- ☐ **July 1977**
- ☐ **August 1977**
- ☐ **September 1977**
- ☐ **October 1977**
- ☐ **November 1977**
- ☐ **December 1977**

Send check or money order to:

ASTRONOMY
411 E. Mason St. — 6th Floor
Milwaukee, WI 53202

Date:________________

Name ____
(please print)

Address ____

City________________ **State/Prov.**____________ **Zip**________

Allow 6-8 weeks for delivery

SKY ALMANAC

MARS AT ITS' BEST

January Satellites of Jupiter
12:00 p.m. EST, 9:00 p.m. PST

1	42103	• ••● •	16	13042	••● ••
2	43012	• •●• •	17	34102	• • •●•
3	4310	• • • ●	18	43201	•• • ●•
4	43201	• •• ●•	19	4320	• •• ●
5	41302	• ••●•	20	40132	• ●•••
6	40123	• ●•••	21	41203	• •• ● •
7	42103	• ••● •	22	42013	• • ●• •
8	2403	••● •	23	4102	• •● •
9	3042	•● • •	24	34102	• • •●•
10	3104	• •● •	25	32041	• • ●••
11	32014	• • ●• •	26	31204	• • •● •
12	13024	••●• •	27	01324	●•• • •
13	01234	●• •• •	28	12034	• • ● • •
14	21034	••● • •	29	20134	• ●• • •
15	20134	•● • • •	30	10324	• ●•• •
			31	30124	• ●•• •

The four major satellites of Jupiter orbit the planet in periods ranging from less than two days to 17 days. You can see them change position from one night to the next; their motions are often evident after only a few hours' observation. You only need a small telescope to detect all four, and you can frequently make out several in rigidly held (or tripod mounted) binoculars. This table shows the approximate positions of the moons at about 12 p.m. EST on the mornings indicated. The first column on the left shows the date; the second column identifies the moons by their positions relative to Jupiter's disk (1 =Io, 2 =Europa, 3 =Ganymede, 4 =Callisto, 0 =Jupiter's disk). The third column gives the satellites' positions as they appear through a telescope. The orientation of the satellite is given with south up as seen through a standard inverting telescope.

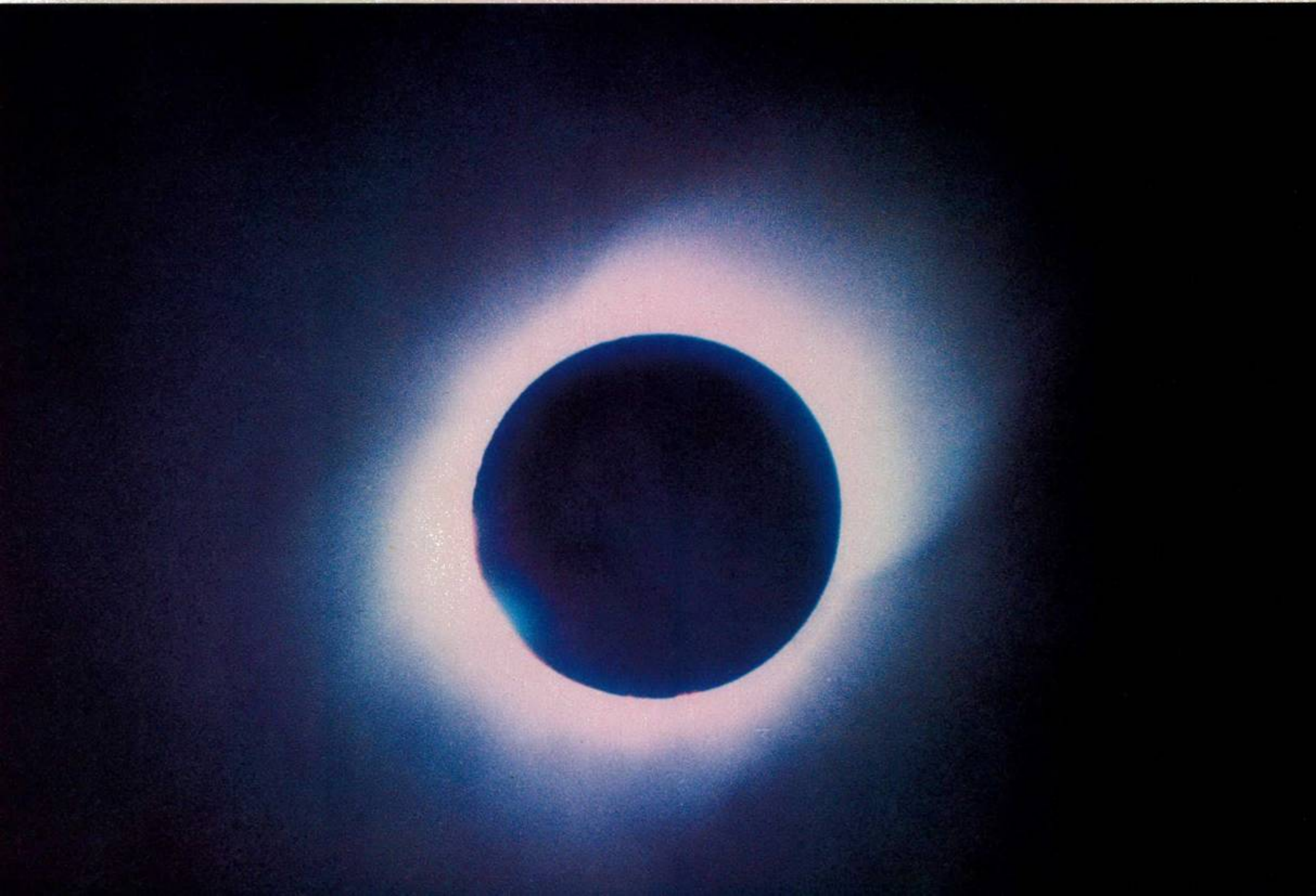
Three bright visitors to the January sky — the planets Mars, Jupiter and Saturn — add a little extra fascination to the abundant observing pleasures available. Don't let the cold of a winter's night deter you from taking a look at one or all of these bright planets. You'll never have a better opportunity during all of 1978 to see all three as bright as they are now.

Mars

On Jan. 22, Mars will reach opposition for the first time since December 1975. Shining at magnitude -1.1 on that date (the planet's brightness having increased dramatically over the previous few weeks), Mars will be outshone only by Jupiter and Sirius, the brightest star; it thoroughly dominates the dim zodiacal constellation Cancer, through which it is moving. The planet rises at sunset and is in the sky all night.

Through the telescope, Mars will present an apparent diameter of 14.3 seconds of arc on its opposition date (about ⅛ the apparent diameter of Jupiter). This is the best time during this appearance of Mars to look for de-

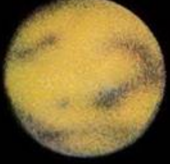
These two photographs, obtained on board the T.S.S. Fairwind in the Pacific Ocean, show two phases of the total solar eclipse of Oct. 12, 1977. Top: Baily's Beads are well seen in this photo (a 1/125 second exposure) obtained just before totality. Bottom: The corona shines in all its splendor as the lunar disk completely covers the sun's face. This is a 1/15 second exposure; both shots were taken on RGB 5247 film, through a 500mm lens at f/6.3. Photographs by Alex S. York.



Planet Finder

Ⓒ Ceres

Jan.	1	15
R.A.	17h02m	17h26m
Dec.	-21°10'	-21°59'
Mag.	+8.4	+8.3



Ⓐ Mercury

Jan.	1
R.A.	17h22m
Dec.	-20°09'
Mag.	+0.4

Ⓑ Mercury

Jan.	15
R.A.	18h05m
Dec.	-22°22'
Mag.	-0.1

Ⓜ Mars

Jan.	1	15
R.A.	8h50m	8h31'
Dec.	+21°43'	+23°20'
Mag.	-0.8	-1.1

Ⓝ Neptune

Jan.	15
R.A.	17h05m
Dec.	-21°24'
Mag.	+7.7

SUN

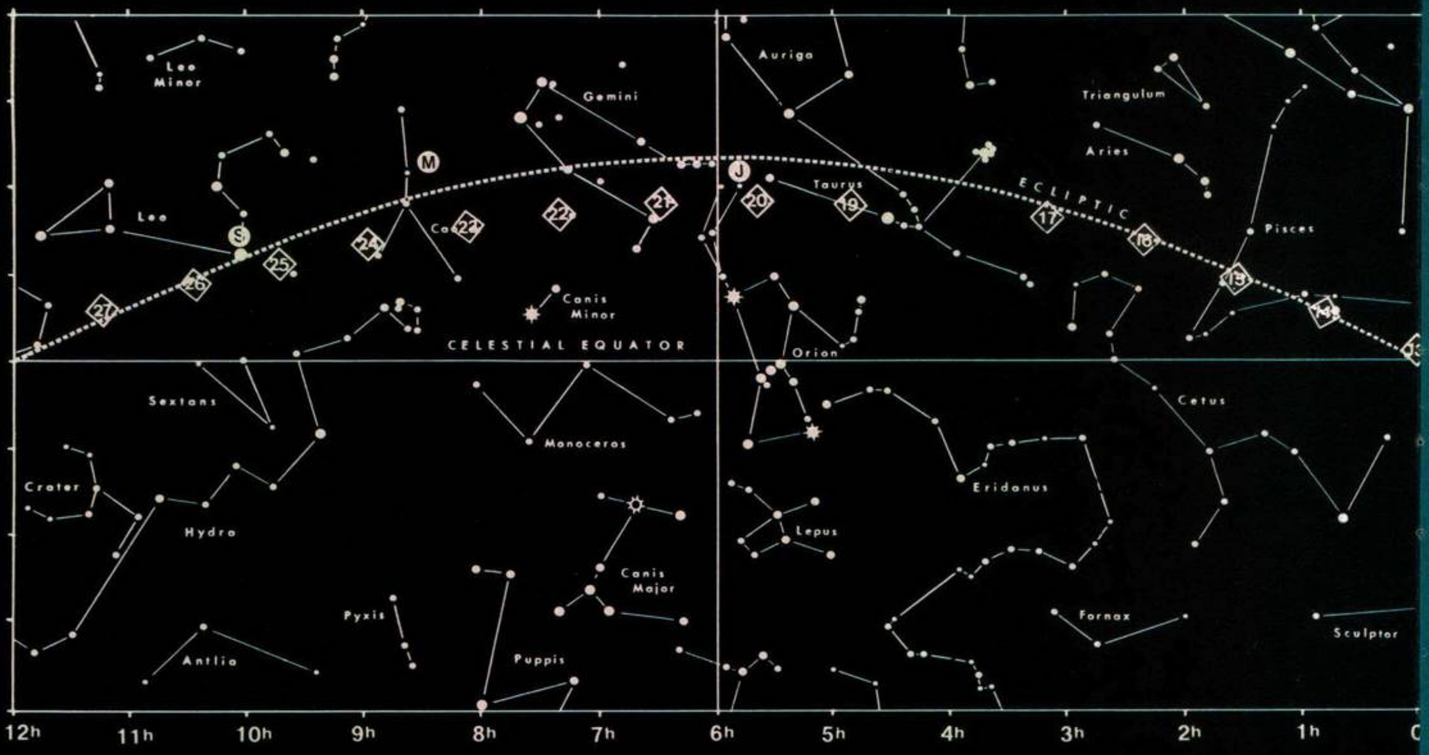
The sun is within the stippled zone throughout the month. Planets and stars near this area are not easily seen.

Ⓢ Saturn

Jan.	1	15
R.A.	10h11m	10h08m
Dec.	+12°44'	+13°01'
Mag.	+0.6	+0.5

Ⓤ Uranus

Jan.	15
R.A.	14h53m
Dec.	-16°12'
Mag.	+5.7



Leo Minor
Gemini
Aurigo
Triangulum
Aries
M
J
Taurus
ECLIPTIC
Leo
S
Ca
22
23
21
20
19
17
16
Pisces
25
24
26
27
15
14
13
Canis Minor
CELESTIAL EQUATOR
Orion
Sextans
Cetus
Monoceros
Crater
Eridanus
Hydra
Lepus
Canis Major
Pyxis
Fornax
Sculptor
Antlia
Puppis
12h
11h
10h
9h
8h
7h
6h
5h
4h
3h
2h
1h

The chart shows the positions of the moon, planets and brightest asteroids for the current month. Letters within the circles correspond to the letters beside each object in the data section above the map. Additional information about each object is given there. R.A. = right ascension and Dec . = declination, the two coordinates used to locate astronomical objects. The general coordinate system is indicated around the edge of the map. Mag . = magnitude, a

January 1978

Ⓥ **Vesta**

Jan.	1	15
R.A.	14h58m	15h25m
Dec.	-10°46'	-12°16'
Mag.	+7.4	+7.3

Ⓙ **Jupiter**

Jan.	1	15
R.A.	5h59m	5h51m
Dec.	+23°12'	+23°13'
Mag.	-2.3	-2.2

Ⓨ **Venus**

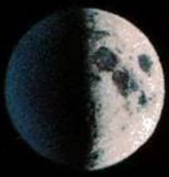
Jan.	1
R.A.	18h22m
Dec.	-23°38'
Mag.	-3.5

Ⓩ **Venus**

Jan.	15
R.A.	19h38m
Dec.	-22°19'
Mag.	-3.5

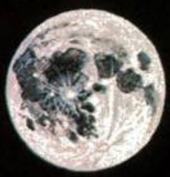
Ⓟ **Pluto**

Jan.	15
R.A.	13h26m
Dec.	+9°26'
Mag.	+14



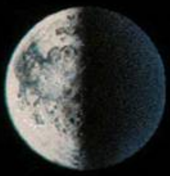
First Quarter

January 15



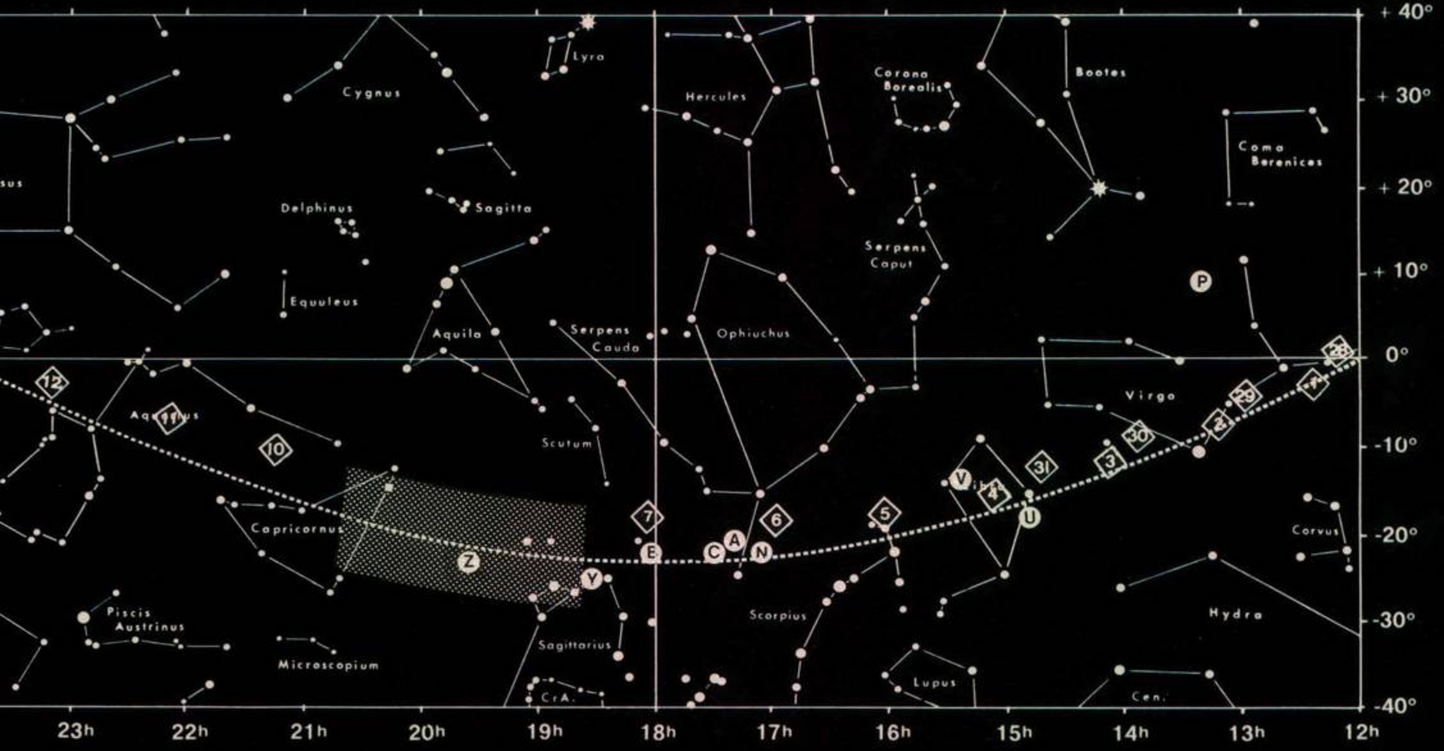
Full Moon

January 24



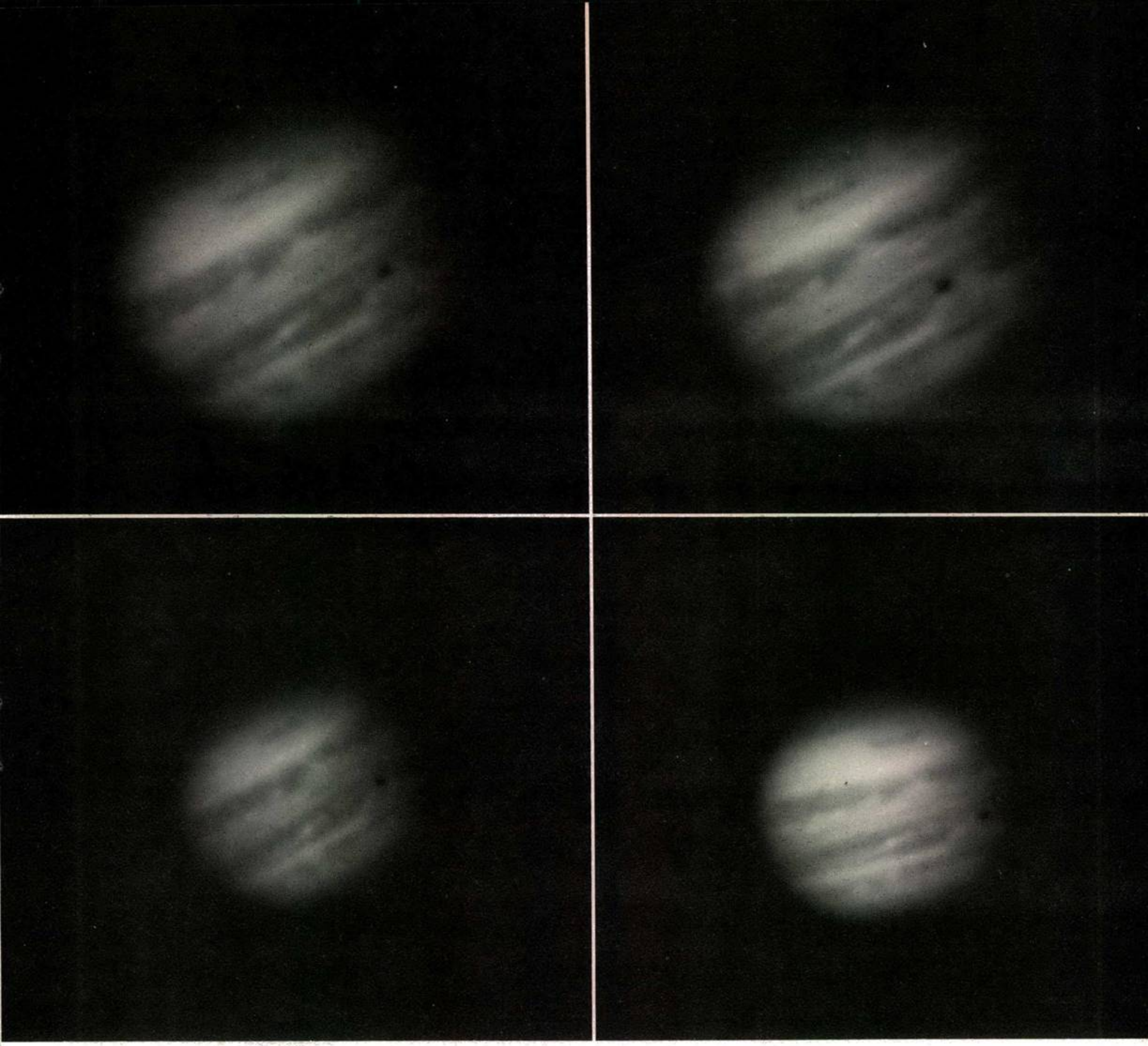
Last Quarter

January 2
January 31



+40°
+30°
+20°
+10°
0°
-10°
-20°
-30°
-40°
23h
22h
21h
20h
19h
18h
17h
16h
15h
14h
13h
12h
sus
Lyra
Cygnus
Hercules
Corona Borealis
Bootes
Coma Berenices
Delphinus
Sagitta
Serpens Caput
Equuleus
Aquila
Serpens Cauda
Ophiuchus
P
Virgo
Aquarius
Scutum
Capricornus
Corvus
Scorpius
Hydra
Piscis Austrinus
Sagittarius
Microscopium
Lupus
CrA.
Cen.
Z
Y
E
C
A
N
V
U
12
11
10
7
6
5
4
31
3
30
2
29
1
28

measurement of the object's brightness. (The minus magnitudes indicate very bright planets.) The diamonds with numbers within them indicate the position of the moon for each day of the month; the numbers correspond to the dates. Positions of the planets are for the 15th of the month except for Mercury and Venus which are shown on both the 1st and 15th. Certain areas of this map and the Star Dome chart overlap each month.



Opposite: The sun was partially eclipsed in the later afternoon from eastern sections of North America on Oct. 12, 1977. In this photo, taken from Scranton, Pa., the sun's disk has a "bite" taken out of it as it shines through clouds. Ektachrome 64 film was used for this 1/1,000 second exposure, taken with a 100mm lens at f/22. Photograph by William P. Duffy Jr. Above: These four photographs of Jupiter show a transit of Io's shadow and the Great Red Spot which (according to the photographer), "appears more prominent than it was last year, (but) is still relatively pale". The photos are one and two second exposures, taken with a Celestron 14 using eyepiece projection on SO-410 film. Photographs by Steve Reed.

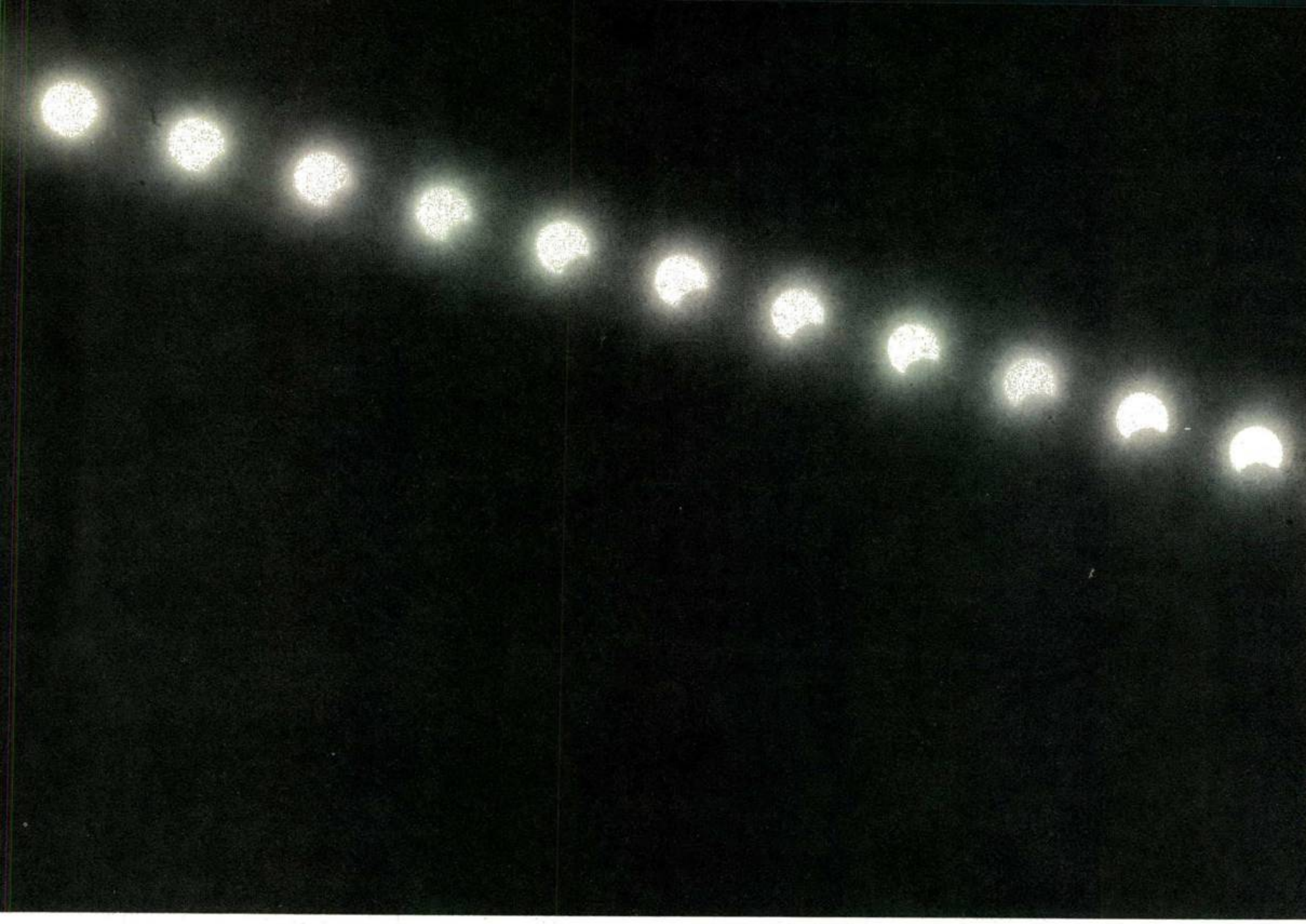
tail on its surface. Because Mars is the only bright planet whose actual surface is visible to the observer using a small telescope (in contrast to the other planets, of which we can see only the tops of their atmospheres), it is perhaps the most fascinating of the planets to watch. Unfortunately, this particular opposition of Mars is not one of the best, as the planet will not approach Earth as closely as it does at other times. Its closest approach will be on Jan. 19, when it will lie at a distance of almost 61 million miles (98 million kilometers). In comparison, Mars can come within 35 million miles (56 million kilometers) of Earth during close oppositions.

Nevertheless, it's certainly worthwhile to observe Mars around its opposition date, to search for detail — dark markings, or one of the polar caps — on its disk. (For information on observing Mars, see "Mars at Opposition", ASTRONOMY, December 1975.) Photographs taken during the course of one night will clearly show Mars' rotation; if you obtain some good pictures, be sure to send them to ASTRONOMY.

Mars will be situated nine degrees north of the full moon on the morning of Jan. 24. Moving retrograde, it will pass from Cancer back into Gemini by mid-February.

Jupiter

The giant planet is located in Gemini during January, southwest of the "twin" stars Castor and Pollux. It shines more brightly than any of the stars or other planets (Venus being invisible this month — see below) at magnitude -2.2 most of January. Jupiter passes almost overhead between 10 and 11 p.m. during January. If you've never noticed Jupiter, take a look this month — you can't miss it!



Satellite Shadows on Jupiter

Date	Satellite	Transit Begins (EST)	Transit Ends (EST)
Jan. 2	1	2:15 a.m.	4:28 a.m.
2	3	5:28 p.m.	8:27 p.m.
3	1	8:43 p.m.	10:57 p.m.
4	2	2:02 a.m.	4:43 a.m.
7	2	3:21 p.m.	6:02 p.m.
9	1	4:09 a.m.	6:23 a.m.
9-10	3	9:28 p.m.	12:27 a.m.
10-11	1	10:38 p.m.	12:51 a.m.
11	2	4:40 a.m.	7:21 a.m.
12	1	5:07 p.m.	7:20 p.m.
14	2	5:59 p.m.	8:39 p.m.
17	3	1:27 a.m.	4:27 a.m.
18	1	12:33 a.m.	2:46 a.m.
19	1	7:01 p.m.	9:15 p.m.
21	2	8:36 p.m.	11:16 p.m.
25	1	2:27 a.m.	4:41 a.m.
26	1	8:56 p.m.	11:09 p.m.
28	1	3:25 p.m.	5:38 p.m.
28-29	2	11:13 p.m.	1:53 a.m.

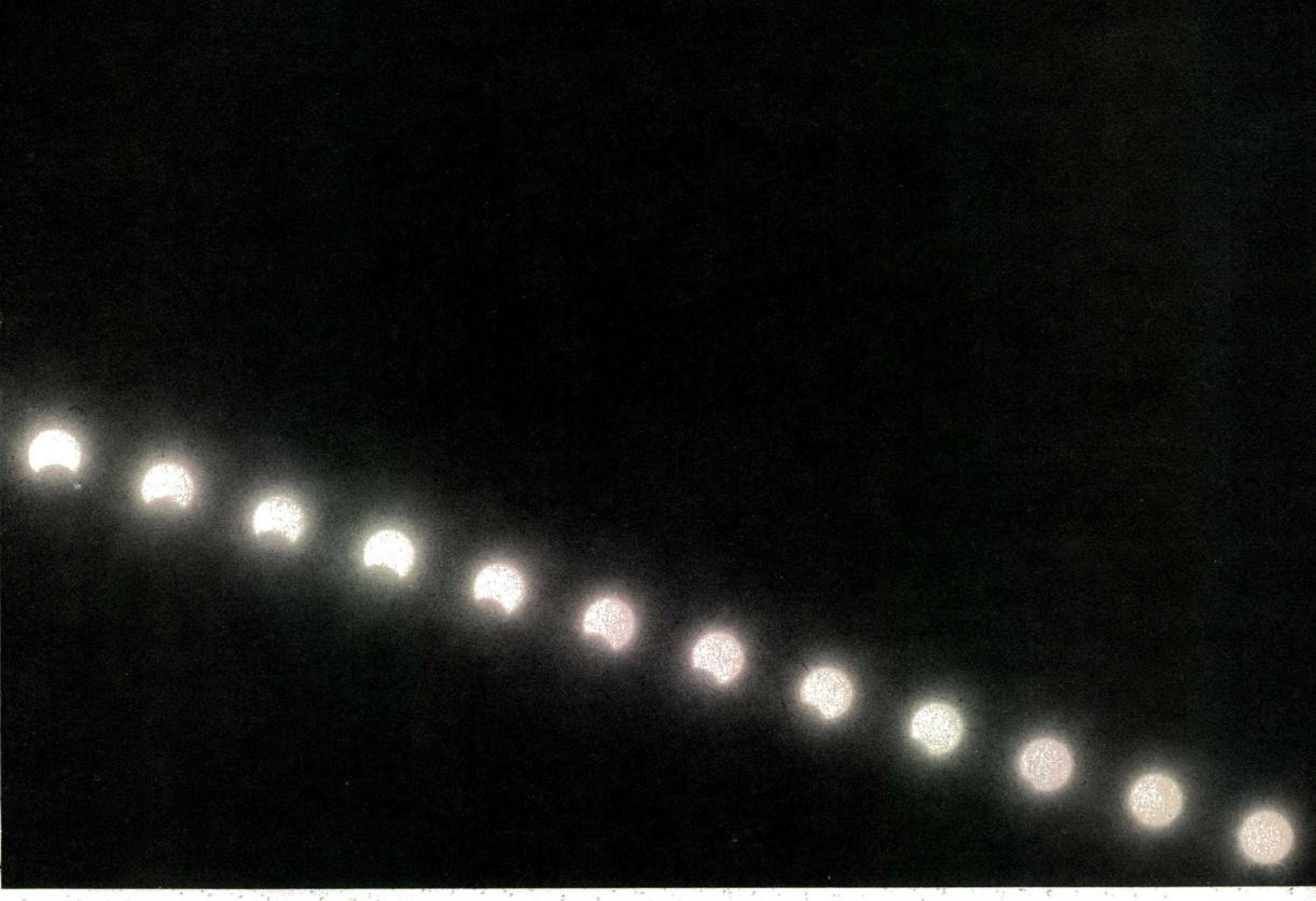
1 = Io
2 = Europa
3 = Ganymede
4 = Callisto

Having passed opposition late in December, Jupiter is now beginning to move away from Earth again. Its distance from us increases from 388 million miles (623 million kilometers) to 409 million miles (657 million kilometers), while its apparent diameter decreases from 44 to 42 seconds of arc — not a very noticeable change, but these small amounts of "shrinkage" from month to month begin to add up after a while. Jupiter will appear a good deal smaller in June than it does now. (For information on observing Jupiter, consult "Observing Jovian Detail", ASTRONOMY, October 1975.)

On the morning of Jan. 21, the planet will be situated five degrees north of the gibbous moon.

Saturn

Technically, we can no longer refer to Saturn as "the ringed planet" because that title implies that there is only one planet with rings — and we all know that Uranus' ring system was discovered last March. However, you can *see* Saturn's rings through even a small telescope; you can't see Uranus' for "love nor money", because Uranus is more distant and its rings are puny



This sequential photograph of the Oct. 12 solar eclipse was obtained from Franklinton, La. As the sun was eclipsed, photos were taken at five minute intervals through a 120 Graflex lens on Panatomic-X film. Each shot is a 1/250 second exposure at f/22. Photograph by Freddie W. Reichard.

compared with Saturn's. One look at Saturn's gorgeous ring system is enough to leave you breathless, no matter how many times you've seen it (see also "Observing Saturn", ASTRONOMY, February 1977).

Saturn will be at opposition next month on the 16th. Until then, it will very gradually grow brighter; its magnitude this month changes from 0.6 to 0.4. Moving retrograde through Leo, Saturn is located very near the first magnitude star Regulus, and will lie little more than one degree away from that star on Jan. 20. Saturn's yellowish color will make a nice contrast with Regulus' blue tint, and the pair will resemble a wide, bright double star.

On the morning of Jan. 26, look for Saturn five degrees north of the nearly full moon. During the month, Saturn rises about three hours after sunset and can be easily seen the rest of the night.

Mercury, Venus

You might get a glimpse of Mercury in the morning sky for a few days on either side of Jan. 11, when the planet is at greatest western elongation. This is not a particularly favorable time to try finding this planet though, because it will not climb very far above the southeastern horizon before sunrise. Diehard observers might try scanning this area with binoculars during morning twilight — you may spot Mercury if you're lucky. Especially try on Jan. 7, when it will be only a few degrees southeast of the thin crescent moon.

Venus is in superior conjunction with the sun (on the other side of the sun from Earth) on Jan. 22 and cannot be seen all month.

Earth

Earth is at perihelion — the point in its orbit at which it is nearest the sun — on Jan. 1 at 6 p.m. EST. At this time, Earth will lie 91,400,000 miles (147,000,000 kilometers) from the sun.

Photographs

The photos of the Oct. 12, 1977 solar eclipse published in this issue represent only a small fraction of those received at ASTRONOMY; others will appear in forthcoming issues. We'd like to thank all those who submitted their eclipse photographs.

If you'd like to submit some of your astrophotographs to ASTRONOMY but aren't sure how to go about doing so, we've just prepared a set of Guidelines for Submitting Photographs that's yours for the asking. Simply drop a note to Judy O'Dair, Editorial Secretary, and request a copy; we'll send you one by return mail.

A note to some of our more experienced astrophotographers: Good photos of some of the lesser-known Messier or NGC objects are always in short supply at ASTRONOMY. If you submit photographs of some of these objects, they'll be good candidates for publication in some of our more specialized observing articles (see, for example, "Observing Planetary Nebulae", ASTRONOMY, August 1977).

Celestron Telescopes—Professional Quality Parts and Accessories

Call us TOLL FREE for our price on the C90 and other fine Celestron models.

As one of the nation's leading Celestron dealers, we want to put you behind the controls of one of these fine instruments. The big news this year is the C90. Check our list of new accessories for this fine telescope.

Celestron C90 Accessories

7.5-22mm Zoom (44X-133X)	**$24.50 ppd.**
Porro Prism	**19.95 ppd.**
40mm. (25X)	**16.95 ppd.**
6mm., 9mm., & 12mm. Ortho	**each 18.95 ppd.**

NEW CELESTRON ACCESSORY CATALOGUE.
Get our free Celestron accessory catalogue and save on standard accessories as well as many of our unique products for your C90, C5, C8 and C14.

For 1978, some exciting new eyepieces to improve your telescope's performance.

For our many friends who have asked us to expand our König line, we offer the exciting 24mm. focal length König ultra-wide-field model. With a field of more than 75°, this is the ultimate in wide 1¼" eyepieces. Multi-coated, of course.

For the 2" O.D. eyepiece devotee, there is the new 55mm. Plössl. Excellent eye relief and a wide field of view. Multi-coated. C14 owners will be amazed at the performance.

16mm. König	**$33.50 ppd.**
24mm. König	**36.50 ppd.**
55mm. Plössl	**79.50 ppd.**

PLÖSSL 55mm
KÖNIG 24mm

MIR-O-TESTER

Get a better mirror! Parabolize it with one of our fine instruments. Order your Mir-O-Tester today!

When your mirror has reached the polishing stage, give it the Foucault test with this fine tester. Our improved Mir-O-Tester offers .001" accuracy with a micrometer-type dial. Kit model is easily assembled from precision parts. Assembly instructions and zonal masks included.

Assembled ...... **$34.95 ppd.** **Kit** ...... **$18.95 ppd.**

DEEP—SKY EYEPIECES

Extra-wide field Kellners for breath taking views of space!

Model A With its special enlarged field lens, it yields the widest field possible. Threaded barrel.

40mm. KMA .... **$19.95 ppd.**

Model B Same wide field as above, only precisely parfocal. We recommend this model for eyeglass wearers.

40mm. KMP .... **$22.50 ppd.**

8 x 50 for Celestron

Our popular wide-angle finder with bracket for C8. Available with True Polaris North indicator reticle.

Model A (T.P.N. reticle)	**$49.95 ppd.**
Model B (Standard cross hair)	**42.50 ppd.**

CELESTRON PRICE QUOTATIONS

CHARGE CARD ORDERS, C.O.D.s

Call Toll Free

(800)-521-2828

all states except Alaska, Hawaii, and Michigan

(9:30 a.m. - 4:30 p.m. Mon. - Sat.)

Second Line (313) 761-0430

A NEW REFRACTOR!

Introducing the compact new 3.1" model by University Optics.

A new, compact, easy to use f/11 refractor with big telescope performance. High quality air-spaced objective. Adjustable equatorial mount lets you follow celestial objects with ease. Coated optics. Includes eyepieces, Barlow, star diagonal, erecting prism, and more. We feel this is the ideal telescope for those of you seeking an easily transportable refractor at a reasonable price. Don't delay, place your order today.

3.1" Refractor .... **$299.50 ppd.**

NEW DUAL FUNCTION RETICLE

The first illuminated reticle designed to meet all of your most critical guiding needs.

This amazing new dual-light reticle lets you select the correct color depending on sky conditions. Flip a switch for amber or special night vision green. 12.5mm. orthoscopic design. Adjustable brightness control. Focusable cross-hairs. 4 feet of power cord. Batteries included. Eyepiece weighs only 4 oz. 1¼" O.D. This fine illuminated orthoscopic will prove to be one of your most valued photographic aids. .... **$39.50 ppd.**

VARIABLE-POWER BARLOW

Our new Professional Series Barlow is one of the world's finest! While it was designed to fit the Celestron, this fine variable telenegative amplifier gives flawless performance in any telescope. The lens slides in a precision brass cell allowing the power to be varied between 2X and 3X. Brass construction with a satin chrome finish. The lens diameter is 27mm. Coated optics. 1¼" O.D.

Variable Barlow .... **$33.50 ppd.**

ACCUSTAR

Enjoy your telescope more. Get sidereal time any place, any time, instantly!

Learn how to use your telescope's setting circles, how to point your scope, and the importance of sidereal time in astronomy. We feel that no telescope owner should ever be without Accustar. You get the Accustar instrument, Sky Finder overlay, and 90-page textbook.

$11.95 ppd.

ZOOM FROM 8.4 to 21 mm.

This is the same fine quality zoom eyepiece we have sold through the years and we have refined it even more! Built-in astro filter adapter at no additional cost. Coated lenses with precision construction throughout. 1¼" O.D. Smooth zoom action for those close-up views. Truly an excellent value. .... **$32.50 ppd.**

PARFOCAL EYEPIECES

Fine quality orthoscopic eyepieces at reasonable prices.

These precisely parfocal 4-element orthoscopics are unexcelled in color correction and resolution. Fully coated optics with a nice 45° field. Standard 1¼" O.D. barrel with built-in filter adapter. Whether for use in the research laboratory or in the home observatory, these are the eyepieces you can count on.

Focal lengths: 4, 6, 9, 12.5, 18, and 25mm. .... **each $18.95 ppd.**

PHOTO-VISUAL MOUNT

Custom engineered for the astro-photographer, this sturdy 2" O.D. mount stands less than 2¾" high. There is no vibration and no vignetting of the light cone. Fits any size reflector tube. Optional accessories include 2" camera adapters and 1¼" eyepiece adapter.

PV Mount .... **$45.00 ppd.**

DEEP-SKY BINOCULARS

Our 11 x 80 and 20 x 80 giant binoculars will meet your most critical deep-space viewing requirements.

We improved the quality on these popular 80mm. binoculars even more! They now feature UV coated objectives in addition to fully coated eyepieces. Perfect for astronomy or nature study. Center-focus design with a reinforcing bridge between the objectives to protect collimation. We suggest the 11-power model for rich-field observation of the stars. Rubber eyecups and camera adapter included.

11 x 80 or 20 x 80 .... **$145.95 ppd.**

COLLIMATION CERTIFICATE. Each instrument is supplied with a certificate of collimation showing how it conformsito our rigid astronomical alignment requirements. A University Optics first!

PROFESSIONAL FOCUSING MOUNTS

UNIVERSAL. Our most popular mount. We have sold this helical rack and pinion for years with excellent results. Cheap copies have appeared, but they have never duplicated its superior design. Fits all tube sizes. 1¼" I.D. .... **$15.95 ppd.**

VEGA 1. A truly unique mount. Mount rotates 360° on base. By removing one screw, top portion of mount can be removed for first-focus photography. Helical rack and pinion has over 3" travel. Base to fit your tube or available flat. 1¼" I.D. Thumbscrew holds ocular. .... **$29.95 ppd.**

VEGA 2. When professional telescope makers choose a big mount for 8" or larger scopes, this uhit fills the bill. Takes the giant 2" O.D. eyepieces as well as 1¼" O.D. units. Cast aluminum construction with helical cut rack and pinion. Thumbscrew holds ocular. The large focusing knobs make using it a pleasure. ...... **$28.95 ppd.**

PROFESSIONAL EYEPIECES

Through the years, the ones they have all tried unsuccessfully to duplicate.

The high quality of our Professional Series eyepieces has been well established over the years in every part of the world. Camera quality orthoscopic optics with multi-coating for maximum light transmission. Warranted to equal or exceed the performance of any eyepiece sold today or your money refunded. Each comes with fitted carrying case.

4mm., 6.8mm., 10.2mm., 16mm., and 28mm. ...... **each $33.50 ppd.**

NEW FREE CATALOGUE
GIFT WITH EVERY ORDER

UNIVERSITY OPTICS INC.

2122 E. Delhi Rd.
Ann Arbor, Mich. 48106

WEST COAST OUTLET
UNIVERSITY OPTICS WEST
P.O. Box 6038, Phone (213) 541-4331
Rolling Hill Estates, CA. 90274

SPACE 1978

A new art reprint calendar from ASTRONOMY

ASTRONOMY magazine proudly presents SPACE 1978 — an exciting new art and photography calendar depicting the awesome beauty of space and astronomy in vivid breathtaking color.

SPACE 1978 features a collection of full color varnished reproductions of some of the best cosmic art and photographs that have appeared in ASTRONOMY . . . and each is accompanied by a short, easy-to-understand description! From the ruddy glow of interstellar gas clouds and raw energy pouring from mysterious black holes and quasars . . . to the exploration of distant planets and the sheer beauty of the star-filled sky . . . the colorful, pictorial universe is displayed in a format that "begs" that the subjects be framed.

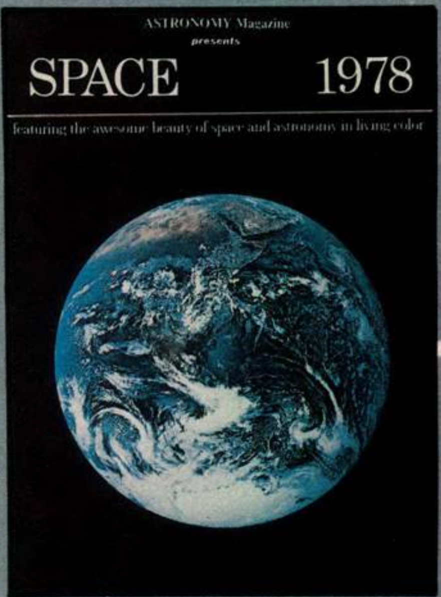
Printed on coated 80 lb. paper and varnished, SPACE 1978 is spiral bound and "hole punched" for convenient hanging. Each reproduction is surrounded by a narrow white border for greater ease in framing . . . and complete framing instructions are provided!

Hallmarks of ASTRONOMY's quality and beauty epitomize this distinctive calendar — whether the illustrations are framed immediately, or the calendar hung and used throughout the year.

July
August
Ma
Febr
April
September
January 1978

Exciting
Features Include:

- **Full color, varnished art & photos**
- **Framing instructions provided**
- **Punched for hanging**
- **Planet oppositions & special sky events noted**
- **Room to jot birthdays & other appointments**
- **1978 Calendar**


ASTRONOMY Magazine
presents
SPACE 1978
featuring the awesome beauty of space and astronomy in living color

Size: 8-3/4" x 11-3/4"

SPACE 1978 is a timeless gift.

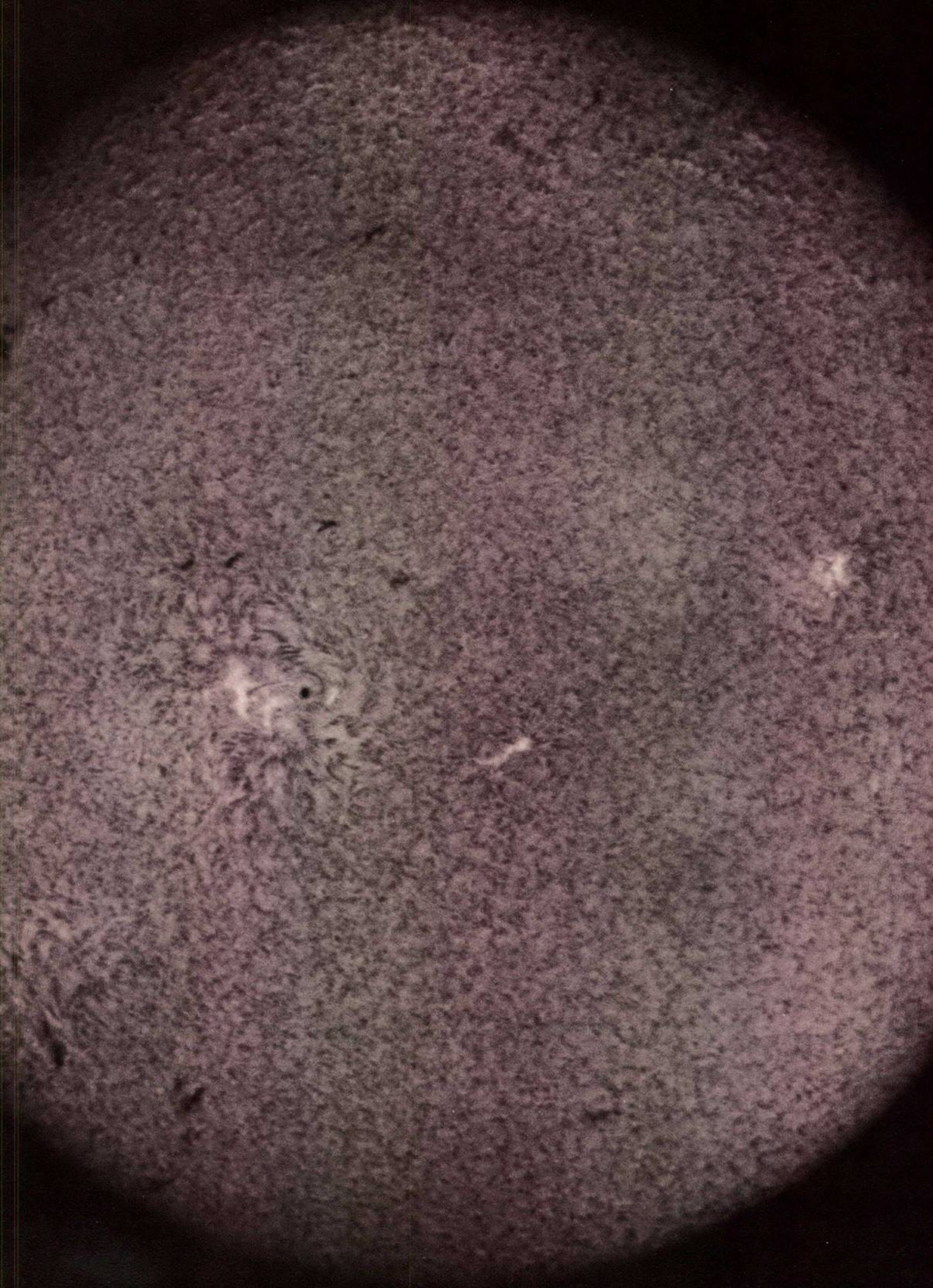
Order *now* for the 1977 holiday season.

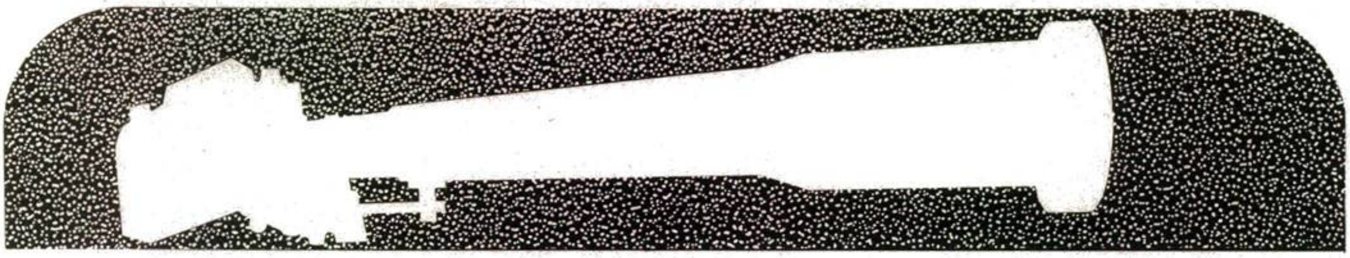
only $4.50 each

(Include 75¢ per order for shipping & handling.)

ASTRONOMY
411 E. Mason St., 6th Floor
Milwaukee, WI 53202

Please send me ______ copies of ASTRONOMY's SPACE 1978.
Enclosed is ______ (including 75¢ for shipping and handling).
Send check or money order to:
ASTRONOMY
411 E. Mason St., 6th Floor
Milwaukee, WI 53202
Date: ______
Name ______
(Please Print)
Address ______
City ______ State/Prov. ______ Zip ______





PHOTOGRAPHY IN ASTRONOMY

Photographing the Sun in H-Alpha

by

Edwin Hirsch

Seeing and photographing the sun is a wonderful way to observe. The sun is accessible to everybody; its bright disk is often peppered with sunspots that you can observe by projection with the smallest telescopes. But if you want to really probe the sun, peruse the layers of its atmosphere, photograph rapidly changing solar storms, and view a prominence's growth and decay — while recording it all on film — then Hydrogen-alpha (called H-alpha or H-α for short) observing and astrophotography is just the thing for you.

What is H-alpha? It's a spectral line emitted and absorbed by hydrogen atoms. It's found at the deep red end of the visible spectrum at a wavelength of 6,562.81 Ångstroms. It operates in interstellar space as the major reason lots of nebulae glow red. On the sun, you'll find hydrogen both emitting and absorbing H-alpha light — absorbing it in the slightly cooler places and emitting it in the hotter or more excited places. But you can't usually see it with a telescope.

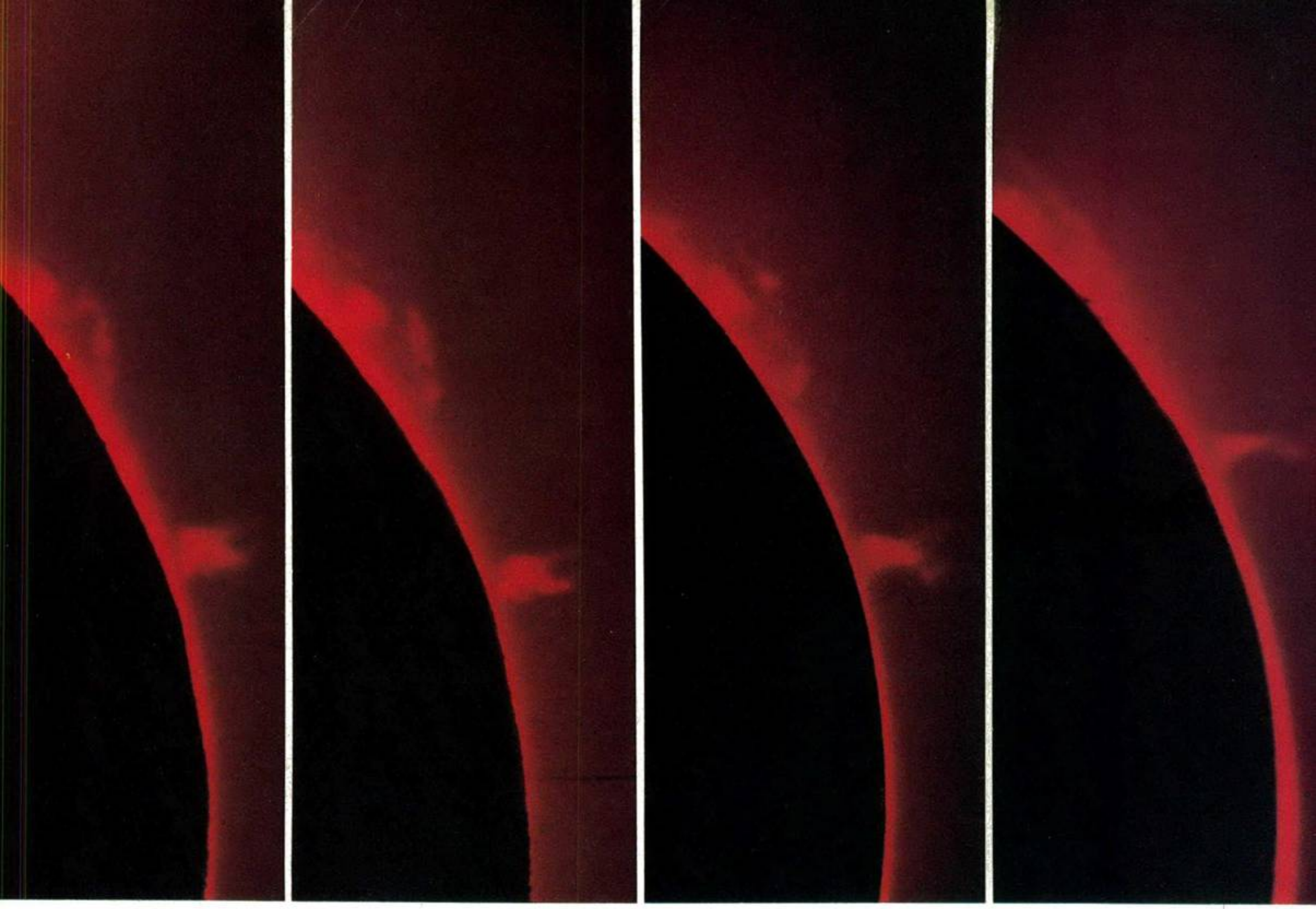
Normally, light from the sun contains all wavelengths visible to your eyes, missing just a few that are absorbed very strongly by atoms fairly high in the solar chromosphere. H-alpha is one of the regions of strong absorption, but it's swamped by all the adjacent wavelengths, and H-alpha features are washed out in the glare. If you could stop all but the H-alpha light, then you could see H-alpha features! Fortunately, modern filters (ranging in price from a few hundred dollars to about $1,000) are now readily available, and they can do just that. Nearly all light but H-alpha is stopped, allowing the H-alpha to come through to your eye or camera.

Fine photographs of solar activity are not necessarily the provenance of professional astronomers alone! This H-alpha filtergram, taken Nov. 9, 1975, shows a sunspot and two active regions of appreciable size. The equipment was an eight inch Schmidt-Cassegrain stopped down to about 50mm (even a small refractor would provide nearly equivalent results), so that its f-ratio became f/45; an ATM model Daystar Hydrogen-alpha solar filter, and a Laborec camera body. The film was Kodak's SO-410, exposed for 1/8 second. Photograph by Edwin Hirsch.

With a combination of telescope and H-alpha filter, delicate features such as plage, filaments, magnetic lines, fibrils, sunspots, prominences and the cataclysmic explosions of solar flares come alive. The chromosphere shows us its many thousands of faces — an endless variety of subject material for H-alpha photographers — in pictures called *filtergrams*.

In years past, narrow-band observations and photography in H-alpha light had been primarily in the hands of the professional astronomers. Their spectrohelioscope and narrow-band quartz/alcite Lyot filters were not readily available. Filters were very expensive, and some took years to construct — so you generally had to be content with sunspot observations in white light. Today filters can be fabricated that transmit essentially one wavelength of light, while rejecting the balance of energy at other wavelengths.

There are two basic types of filters available, and with them you can make two different types of observations. The critical difference is the filter's *bandwidth* (the amount of stray light that comes



Prominence photography is no dull or static preoccupation — prominences change and evolve within the course of a few hours! On Dec. 19, 1976, these prominences were captured on film using a Daystar filter on a stopped down Schmidt-Cassegrain. From left to right, they were taken at 10:05 a.m., 10:35 a.m., 11:35 a.m., and 14:35 (afternoon) CST. Note the fascinating changes between each frame and the next, and the dramatic change in the three hours between the last two. Photographs by Harry W. Miller.

through), which determines what you do with it and what you can see.

Wide-band filters (such as the Prominence Probe by Roger Tuthill) have bandwidths of three to four Ångstroms (an Ångstrom is a unit of wavelength measurement), and are suitable for viewing bright H-alpha features, such as solar prominences, against a dark background. With a wide-band filter, plus a gadget to block the brighter disk of the sun, you can search the solar limb looking for elusive streamers of activity.

Narrow-band filters (such as Day Star by Del N. Woods and Skyspear by Carson) have bandwidths ranging from 1 to less than 0.5 Ångstroms. With narrow-band filters, so much "continuum" light is excluded that you can see and photograph the delicate features of the solar disk, activity around sunspots, solar flares, prominences seen against the sun in silhouette (filaments), as well as prominences at the limb of the sun.

Wide-band filters usually consist of a single *interference* filter — a special filter made by depositing many layers of dielectric materials (like the magnesium fluoride coatings on your camera lenses, but far more complex) on a quartz support. The filter only transmits light at wavelengths that can "dance" down the complex of spacings designed for just one wavelength and a "band" around it. In order to keep the layers at the proper spacings, the filter has to be held in a temperature controlled housing, which is usually sold with the filter.

Narrow-band filters contain a *broad band* filter, and behind it a superfilter called a *Fabry-Perot Etalon* — a bigger, more precise, fancier version of an interference filter that narrows the bandpass of the wide-band filter. Temperature control is critical, so the units are always sold with an integral temperature controlled "oven".

Such finicky filters, though generally pretty rugged, impose some limitations on the user. In order that they transmit the narrow band of wavelengths they're designed for, they can only accept a thin beam of light from the telescope. F/30 is the usual limit, so if your telescope has a 60 inch (1,500mm) focal length, you'll have to stop it down to two inches (50mm) or less to get the filter to perform to specs. But that's just as well because the heat from a normal solar image at focal ratios smaller than f/30 can play havoc with the temperature controller and could damage the delicate filter coatings. F-ratios larger than f/30 are okay; f/40 or f/50 are often most practical.

The filter is usually mounted on the telescope just ahead of focus — which is easy to do with refractors and catadioptric telescopes, but not with most Newtonian reflectors because of limitations in the height of the focuser. Perhaps the best solution is to build a special telescope for the filter. Using a readily available lens like the two inch diameter lens of 48 inch focus (such as A. Jaegers' #1B 1520), you can make a fine trial telescope. Jesse Knight offers a telescope objective or special auxilliary lens ideal for H-alpha work. If you own one of the catadioptrics, there are plenty of firms ready to sell handy adapter kits and parts along with the filter itself.

You'll find most telescopes must have their apertures reduced to provide correct focal ratios. Also, in order to keep telescopes and filter optics cool, an energy rejection filter is usually placed over the reduced aperture. This filter rejects at least 80 percent of the off-band energy while transmitting about 92 percent of the energy at design wavelength.

Solar H-Alpha Astrophotography

Photographs of the chromosphere are properly called *filtergrams*. This kind of astrophotography can be done very successfully in metropolitan areas as well as in the countryside. In fact, slight haze or smog conditions usually will enhance the image by virtue of a steadier atmosphere. The H-alpha filter helps to penetrate the haze and smog.

The basic setup is simple: The telescope is stopped down to f/30 or f/45 and has an extra energy rejection filter over the lens. Near focus is the filter; mounted behind it is your camera or eyepiece.

You may want to shade yourself by making a sunshade out of cardboard. It should be large enough to put your head in its shadow and mount it on the rear of your telescope. The sunshade will keep you cool in the summer, and help keep your eyes out of direct sunlight, which is important for viewing and focusing solar images.

You may also try an opaque cloth (such as a photographer's black cloth) over your head, the filter, and the focusing device. This puts your eyes in a portable darkroom, thereby eliminating almost all daylight so the chromospheric image becomes alive with detail. Focusing becomes a lot easier.

While you can use any single lens reflex camera, the easiest cameras with which to *see* the deep red filtered images are those with hi-magnification dioptric reflex viewfinders such as the Miranda Laborec 35mm camera with its aerial focusing screen. This kind of camera gives you the brightest image to focus, and has none of the coarse grainy appearance found with a ground glass screen.

Use of the proper film is of prime importance in making filtergrams. There used to be only one available: SO-410, a black and white panchromatic film with high sensitivity in the red end of the spectrum. Kodak is now replacing it with a new, less grainy film called SO-115, which can be obtained through Kodak professional dealers in 35mm 36-exposure rolls (CAT #129-7563) for $2.35 per roll.

Photography at the long f-ratios typically needed for filters means taking filtergrams at 1/4 or 1/8 second as standard exposures with an f/45 telescope. For prominence photos, the exposure range is from one to three seconds. Using a faster f-ratio of f/30 lets your exposure range from 1/15 to as high as 1/60 second, with prominence exposures in the 1/2 and 1/4 second range. Of course the time of year, time of day, altitude of the sun, and general sky conditions affect exposure.

Since H-alpha light is monochromatic, color film really has no advantage in H-alpha photography. Color film does not have the contrast needed to make filtergrams, but for prominence photos, it does produce very pretty results as seen on pages 6 and 7 .

To develop SO-410 or SO-115, try Kodak D-19 developer — diluted one to one — using a temperature of 68 to 70 degrees Fahrenheit for three to four minutes. Use a short stop and a fresh hypo bath, wash for 20 minutes, and then use a wetting agent such as photoflo. Hang your film up in a dust free area. Don't wipe the film; just let it dry by itself. Developing times and temperatures are flexible; your own experience will let you experiment freely. D-19 can be used full strength up to 80 degrees for the limit of eight minutes for superhigh contrast before chemical fog will enter the picture. Try to make negatives that print well on grades three, four and five enlarging paper. You'll find some dodging will be helpful in making the best filtergram prints from H-alpha negatives.

At your telescope, knowing the exact moment to release the shutter comes from experience — the same kind of experience as in planetary and lunar astrophotography. Let the image settle down after the last exposure and wait for scintillation to let up enough to make your exposure.

Finally, when you photograph an event such as a solar flare, try to keep taking photos as fast as possible. Remember that a few good filtergrams are better than many bad ones.

H-alpha filters can add a new dimension to your observing experience! In fact, you can make your telescope into a solar observatory. Observing our sun in H-alpha light — essentially monochromatic light — is unlike any other observing experience you may have had. It usually takes quite a bit of "learning", but as your observing experience grows, you'll become aware of even the more subtle solar features.

Edwin Hirsch is president of Telescopes and Astronomy, a dealership for Celestron, Daystar, Meade and Unitron. He started out as a photographer, but became seriously interested in astronomy about 12 years ago. He has been involved with solar observing for the last three years.

Meade Instruments: fastest delivery in the West... or East

As America's number one supplier of telescope accessories, our watchword is ***service.*** Whether placed by phone or mail, your order is shipped by First Class Mail or United Parcel Service within 24 hours. Our inventory of eyepieces, filters, camera adapters, viewfinders, and other telescope parts is the largest in America. Ready for the fastest delivery in the West. . .or East.

FREE ACCESSORY CASES!

Now you can purchase Meade astronomical products and receive a foam-fitted accessory case absolutely FREE!

We will send you **free of charge** one of our **Model #51 Accessory Cases** (see Item No. 27) **with any purchase of $25.00 or more.** This accessory case sells for $7.95 if purchased separately.

Or, if you purchase **$50.00 or more** in Meade products, you will receive **free of charge** one of our **Model #54 Deluxe Accessory Cases** (see Item No. 28). This accessory case sells for $10.95 if purchased separately.

This free accessory case offer expires January 31, 1978. Maximum 2 free cases per customer. **Orders to receive free accessory cases must mention this ad to qualify.**

Rack-and-Pinion Focusers - Three superbly engineered focusers. Thousands in use by amateurs everywhere. *See Items #21, 22, 23.*

Camera Adapters - Precision machined adapters for quick attachment of cameras to your telescope. *See Item #20.*

Zoom Orthoscopic Eyepiece-8.4-21mm (1¼" O.D.). *See Item #8.*

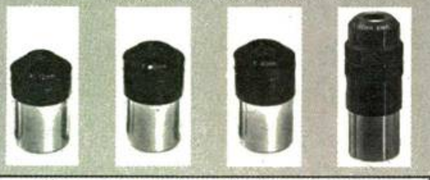
2" O.D. Eyepieces - *See Items #10, 11.*

8 x 50 Right-Angle Viewfinder
With new Kellner 30mm Extra-Wide-Field crosshair eyepiece. *See Item #31.*

Series 1 Orthoscopic Eyepieces (1¼" and .965" O.D.) - Classical 4-element design, 45° field, available in 8 focal lengths. *See Items #2, 3.*

Research-Grade Orthoscopic Eyepieces (1¼" O.D.) - Multi-coated, 4-element, parfocal. The finest astronomical eyepieces obtainable. *See Item #4.*

Series 1 Kellner Eyepieces (1¼" O.D.)
Fine performance at a moderate price. Two 40mm wide-field models available. *See Items #5, 6.*



Illuminated Reticle Eyepiece-For precise photographic guiding and accurate measurement of angular distances. *See Item #14.*

2x-3x Telenegative Amplifiers - The world's finest Barlow lenses, 26mm clear aperture, 1¼" O.D. *See Items #16, 17.*

PRODUCT DATA

1 - PHOTO-VISUAL COLOR FILTERS - Top quality optical glass, dyed in the mass, with excellent spectral homogeneity. Mounted in machined metal cells which thread directly into all our 1-1/4" "Series 1" and "Research-Grade" eyepieces. Filters may be piggybacked. Listed by Wratten No. and color:
#8 Light Yellow - #11 Yellow-Green - #12 Yellow - #21 Orange - #23A Light Red - #25A Red - #47 Violet - #58 Green - #80A Medium Blue - Polarizer (30% transmission) Each Filter:...**$4.95 ppd.** - Set of any 6:...**$28.50 ppd.** - Full set of 10:...**$46.50 ppd.**

2 - Series 1 ORTHOSCOPIC EYEPIECES (1-1/4" or .965" O.D.) - These Meade eyepieces are the largest selling orthoscopics in the world. Classical 4-element design, 45° field, fully coated, with precise corrections for color and field flatness. All 1-1/4" barrels are threaded to accept our photo-visual filters directly. **Focal lengths: 4, 6, 9, 12.5, 18, 25mm - Each. . .$17.95 ppd.**

3 - Series 1 PARFOCAL ORTHOSCOPIC EYEPIECES (1-1/4" O.D.) - As in (2) but parfocalized in all 6 focal lengths. **Each:...$19.25 ppd. - Set of any 4:...$72.95 ppd. Set of any 5:...$90.00 ppd. - Additional eyepieces: each...$18.00 ppd.**

4 - RESEARCH-GRADE ORTHOSCOPIC EYEPIECES with Multi-Coated, Parfocal Optics (1-1/4" O.D.) - Acclaimed by amateur and professional astronomers everywhere to be the world's finest eyepieces. These 4-element systems are unsurpassed in resolution, color correction, and flatness of field. Air-to-glass surfaces are 5-layer multi-coated for maximum image contrast and light transmission. 45° field. Precisely parfocal. Barrels are threaded to accept our filters directly. **Focal lengths: 4, 7, 10.5, 16.8, 28mm each...$32.95 ppd. - Set of any 4:...$124.00 ppd. Set of any 4 plus Res. Gr. Erfle 20mm...$156.00 ppd. - Full set of 5 Res. Gr. Orthoscopics plus Res. Gr. Erfle 20mm...$185.00 ppd.** (Sets of 4, 5, or 6 eyepieces are shipped in fitted carrying case at no additional charge, see #27).
RESEARCH-GRADE ERFLE 20mm (1-1/4" O.D.) - Parfocalized with our Research-Grade Orthoscopics and 5-layer multi-coated. Apparent field in excess of 75° for breathtaking wide-angle observations. Barrel accepts our filters directly. **$39.50 ppd.**

5 - Series 1 KELLNER EYEPIECES (1-1/4" O.D.) - Highly corrected, 3-element design, fully coated. The best in moderately priced eyepieces. Barrels threaded for our filters. **Focal lengths: 6, 12, 25mm each. . .$12.50 ppd. - 40mm Wide Field. . .$14.50 ppd.**

6. - KELLNER 40mm EXTRA-WIDE-FIELD (1-1/4" O.D.) - Yields widest field obtainable in 1-1/4" O.D. Enlarged field lens and special field-flattening optics with long eye relief. Barrel accepts our filters... **$22.75 ppd.**

7 - Series 1 ERFLE 20mm (1-1/4" O.D.) - An advanced 5-element system with fully coated, color corrected optics. Wide 65° field. Barrel accepts our filters. **$27.95 ppd.**

8 - ZOOM ORTHOSCOPIC EYEPIECE (1-1/4" O.D.) - Zooms instantly from 8.4mm to 21mm, with excellent image corrections at all powers. Wide 50° field at 8.4mm. Fully coated optics. . .**$32.95 ppd. - Filter adapter #004**: couples our filters to above eyepiece . . .**$1.00 ppd.**

9 - ZOOM KELLNER EYEPIECE (.965" O.D.) - Fine 4-element design. Zoom range 7.5mm-22.5mm. Fully coated optics...**$27.95 ppd.**

SUPER-WIDE-FIELD EYEPIECES (2" O.D.) - Premium-quality wide-field eyepieces for 2" focusers. The ultimate in rich-field performance. Fully coated.
10 - ERFLE 32mm (2" O.D.) - Sophisticated 5-element optical system. Wide, flat 65° field...**$75.00 ppd.**
11 - KELLNER 60mm (2" O.D.) - Low power, long eye relief. Ideal for deep-space observations...**$42.50 ppd.**

12 - ERFLE 32mm (1-1/4" O.D.) - As in (10), but with standard 1-1/4" barrel, threaded for our filters. 60° field...**$75.00.**

13 - .965" EYEPIECES - (phone, or request catalog, for details).

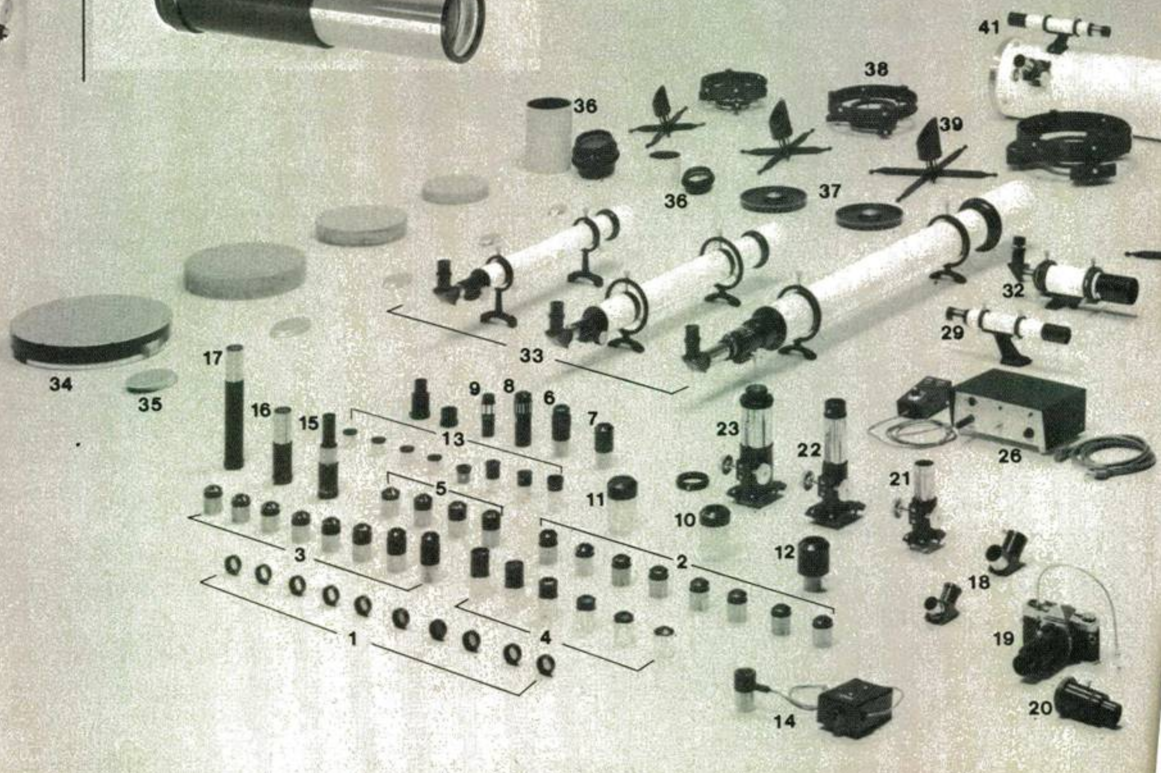
14 - ILLUMINATED RETICLE GUIDING EYEPIECE (1-1/4" or .965" O.D.) - For professional-level photographic guiding. Kellner 12mm optical system, with precisely focusable 4-line glass reticle. Remote brightness control and 3 ft. cable. (Extension cables available) Complete...**$37.50 ppd.**
Micrometer Reticle: Full-field scale for accurate measurements of double star separations, planetary angular diameters, etc. Interchanges with standard 4-line reticle...**$11.95 ppd.**

15 - 2X ACHROMATIC BARLOW LENS (1-1/4" O.D.) - A high resolution, coated, negative achromat with excellent corrections for spherical and chromatic aberrations. **$18.75 ppd.**

16, 17 - 2X AND 3X TELENEGATIVE AMPLIFIERS (1-1/4" O.D.) - The world's finest Barlow lenses. Full 26mm clear aperture, with virtually flawless optical corrections at all photo-visual wavelengths. Produces optimum performance on telescopes of any focal ratio. Fully coated. (16) **2X Model 122...$29.50 ppd.** (17) **3X Model 123...$32.50 ppd. - Combination 2X and 3X Model 124...$39.50 ppd.**

18 - DIAGONAL PRISMS - Quality, right-angle prisms, fully coated. **1-1/4" O.D....$16.95 ppd. - .965" O.D....$12.95 ppd.**

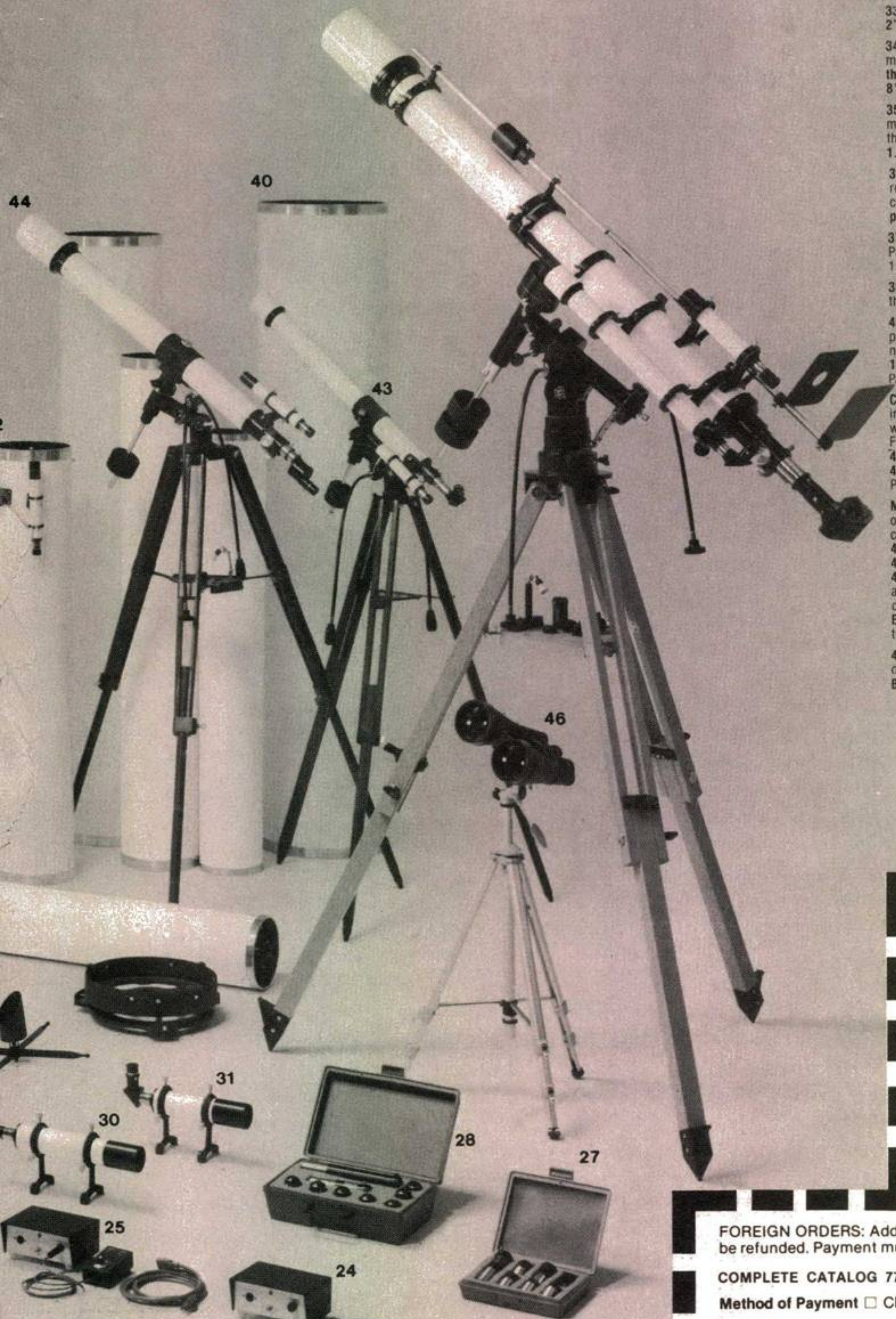
19 - OLYMPUS OM-1 ASTROCAMERA - One of the world's great astrocameras (Phone or request catalog for details.)...**From $229.50.**



20 - DELUXE CAMERA ADAPTERS - Adapt your camera to telescope focuser instantly. Individually machined from solid bar aluminum. All units permit both eyepiece projection and first (prime) focus photography. Specify either .965'' or 1-1/4'' focuser. (If for Celestron, please specify.) All 1-1/4'' units are threaded for our filters. **Pentax, Praktica, Yashica, Mamiva...$15.95 ppd. - Exakta, Nikon, Canon, Minolta, Miranda, Konica...$23.95 ppd. - Olympus OM-1...$24.95 ppd.**

RACK-AND-PINION FOCUSERS - Precision metal construction. All 3 models include helical-cut rack for ultra-smooth focusing without backlash. Universal bases fit all tube sizes. Standard 1-1/4'' eyepiece holders. **Each focuser is guaranteed to be the finest obtainable in its class.**
21 - Model #67 - Strong, lightweight design for 4'' to 10'' telescopes. 2-3/16'' travel. An excellent value...**$15.75 ppd.**
22 - Model #640 - A heavy-duty deluxe focuser for 6'' to 16'' telescopes. Full 3'' travel for both visual and photographic applications...**$26.95 ppd.**

23 - Model #680 - Our finest focuser. Accepts both 1-1/4'' and 2'' eyepieces. Full 3'' travel for photo or visual observing with 6'' to 16'' telescopes...**$29.95 ppd.**



VARIABLE FREQUENCY DRIVE CORRECTORS - Quality, temperature compensated circuitry for precise electronic guiding. Each model will drive telescopes to 14'' aperture. 20 ft. battery cables, instructions included.
24 - Model #24 - Uses 12v. D.C. Frequency variable between 50-70Hz with knob attached to power box. An excellent value...**$49.50 ppd.**
25 - Model #29 - Uses 12v. D.C. Remote control box with fast-slow buttons and variable center frequency dial for tracking at solar, lunar, or planetary rates...**$62.50 ppd.**
26 - Model #33 - Uses 12v. D.C. or 110v. A.C. Other features identical to Model 29...**$89.50 ppd.**

ACCESSORY CASES - Rugged polyethylene, for dust-free protection of eyepieces, filters, Barlows, etc. For either 1-1/4'' or .965'' accessories. Die-cut foam lining.
27 - Model #51 - 7'' x 8-1/2''...$7.95 ppd.
28 - Model #54 - 8'' x 12''...$10.95 ppd.

VIEWFINDERS - Each with coated, achromatic objective and crosshair eyepiece.
29 - 6 x 30mm: Fine, 4° wide-field finder. Thousands now in use. 2-ring bracket included...**$17.95 ppd.**
30 - 8 x 50mm - Large 50mm aperture, Ke30mm Extra-Wide-Field crosshair eyepiece. Sharp, brilliant images... **$27.95 ppd. - Mounting brackets: $7.95/pr.**
31 - 8 x 50mm Right-Angle - 50mm aperture, for both straight-through and right-angle viewing. Prism included... **$34.95 ppd. - Mounting brackets: $7.95/pr.**
32 - 8 x 50mm Right-Angle - As above, but with bracket for Celestron 8 **$44.95 ppd.**
33 - PHOTO-GUIDE TELESCOPES - (Phone or request catalog for details.) **2''...$49.50 - 2.4''... $69.50 - 3.1''... $152.00**

34 - PARABOLIC PRIMARY MIRRORS - Professional quality hand figured Pyrex mirrors, aluminized and quartz overcoated. **Each mirror is guaranteed to reach all theoretical limits of performance. 6'' f/8...$49.95 ppd. - 10'' f/6...$159.95 8'' f/6 or f/7.5...$89.95 ppd. - 12-1/2'' f/6... $239.95 ppd.**

35 - ELLIPTICAL SECONDARIES - For optimum performance with any primary mirrors. Aluminized, overcoated. As optically flat as master opticians can make them. Minor axis sizes shown, postpaid: **1.30''...$9.00 - 1.52''...$12.50 - 1.83''...$14.50 - 2.14''...$17.50 - 2.60''...$21.00**

36 - OBJECTIVE LENSES - As used in Meade guide telescopes and equatorial refractors. Air-spaced, achromatic, fully coated. Mounted in machined, threaded cells. Dewcap and dustcap included. **2'' f/12... $19.50 ppd. - 2.4'' f/15... $34.50 ppd. - 3.1'' f/15...$74.50 ppd.**

37 - SETTING CIRCLES - Die-cast aluminum, 6'' diameter. Machine engraved. Precision guaranteed. Standard 1-1/2'' bore:...**$35.00/pr.** Other bores (from 1/4'' to 2''): **add $1.50 per circle.**

38, 39 - MIRROR CELLS AND SPIDERS/DIAGONAL HOLDERS are available to fit the tubing below. Phone, or request catalog, for details.

40 - FIBERLITE TELESCOPE TUBES - 20% more rigid, yet 40% lighter, than pure fiberglass, with low thermal conductivity. Polished end rings available at nominal cost. Partial price list: **7'' I.D. x 50''...$36.00 - 9-1/4'' I.D. x 60''...$53.00 12-3/8'' I.D. x 62''...$81.00 - 12-3/8'' I.D. x 72''... $92.00**
Packing charge: 7'' and 9¼'' tubes - **$6.00**; 12-3/8'' tubes - **$9.00**

COMPLETE OPTICAL TUBE ASSEMBLIES - Fully Assembled. Each assembly includes the premium quality Meade components described above: Fiberlite tube with end rings, primary mirror and cell, spider and secondary mirror, Model #67 Focuser, 6 x 30mm viewfinder. Shipping charges collect.
41 - 6'' f/8 tube assembly... $155.00
42 - 8'' f/6 tube assembly... $225.00
Packing charge on tube assemblies...**$10.00**

MEADE EQUATORIAL REFRACTORS - Whether beginning or serious amateur, one of these superb instruments will fit your observing requirements. Phone or request catalog for details.
43 - Model #291: 2.4'' Equatorial Refractor...$225.00
44 - Model #300: 3.1'' Equatorial Refractor...$365.00
45 - Models #420 - #440: 4'' Equatorial and Photo-Equatorial Refractors, available with guide telescope, illuminated reticle eyepiece, motor drive, frequency corrector, astrocamera. **From $1175.00**
Equatorial Mounts - Each includes complete mount, circles, 2 cables, hardwood tripod. **Mount for Model #291...$110.00 - Mount for Model #300...$172.00**

46 - 20 x 80mm ASTRONOMICAL BINOCULARS - Coated optics. Magnificent for deep-space observing...**$127.50 ppd.**
Bushnell Tripod: fully adjustable...**$49.50 ppd.**

MEADE INSTRUMENTS

721 West 16th Street, Costa Mesa, Calif. 92627 • (714) 646-9281

MAIL ORDERS: Circle numbers for items desired and write your specific requirements on a separate sheet—or use the order form which accompanies our catalog.

1 2 3 4 5 6 7 8 9 10 11 12
13 14 15 16 17 18 19 20 21 22 23 24
25 26 27 28 29 30 31 32 33 34 35
36 37 38 39 40 41 42 43 44 45 46

PAYMENT: Personal or bank check, money order, or credit card (BankAmericard or Master Charge)

TELEPHONE ORDERS: accepted with payment either COD or credit card (we do not accept collect calls).

SHIPMENT: All orders are processed for shipment within 24 hours of receipt.

FOREIGN ORDERS: Add 20% to cover Air Parcel Post charges—any excess will be refunded. Payment must be made by bank check in $ U.S.

COMPLETE CATALOG 77-C — $1.00 (Catalog free with any order)

Method of Payment ☐ Check or Money Order ☐ BankAmericard ☐ Master Charge

Card No. ______________________ Expiration Date / /

Name ______________________

Address ______________________

City______________ State__________ Zip__________

MEADE INSTRUMENTS

721 West 16th Street, Costa Mesa, Calif. 92627 • (714) 646-9281

GAZER'S GAZETTE

Observing Herschel Objects

James Mullaney

Many observers of deep sky objects, having once surveyed the 105 clusters and nebulae in Charles Messier's well-known catalog, seek a more extensive and challenging roster of subjects to go after. Finding such a list, however, is nearly impossible — unless you want to survey the 7,840 items with NGC numbers! Daunted by the magnitude of such a task, many of you would probably retreat to the safety of the Messier list, relying on an occasional description or "lucky find" to extend your knowledge of deep sky objects.

Nevertheless, there is a list of worthwhile subjects available that would well repay your interest. The list most often mentioned by Messier veterans is the catalog of clusters and nebulae compiled around the end of the 18th century by the great English observer and telescope maker, Sir William Herschel. As part of his grand scheme to study the "construction of the heavens" (as he called it), Herschel arranged his more than 2,500 discoveries into eight categories or classes. These are defined in the table on page 46, which shows the actual distribution of objects by class. As you can see by the table, the Herschel catalog contains no separate designation for galaxies, because at the time Herschel worked, the true nature of galaxies had not yet been discovered; they were simply placed in the "nebulae" classifications. Also Herschel included very few of the Messier objects in his list; he knew of and respected Messier's work, and had no wish to supersede it.

This very fate, however, has befallen the Herschel list; most observers consider it outmoded by Dreyer's **New General Catalogue of Nebulae and Clusters of Stars** (commonly known as the NGC), which was originally published in 1888. This monumental work, together with its two supplements known as the **Index Catalogues** (or ICs), gives the positions and descriptions of nearly 15,000 deep sky objects! Dreyer, unlike Herschel, *did* intend his lists to be exhaustive; all but the very faintest clusters, nebulae and galaxies in the sky have an NGC or IC designation — including all the Messier and Herschel objects!

The Messier list has remained "current" for two reasons: the brightness of its component objects (it includes almost all the brightest objects in the sky), and its handy size — it serves as an excellent introduction to deep sky observing. The Herschel catalog has, for the most part, been superseded by the NGC, and the objects on the list are far more often referred to by their NGC numbers than by their Herschel numbers. Even so, Herschel's designations are interesting and valuable to visual observers, and his system of notation is still used by some star atlases, including the well-known **Norton's Star Atlas**. Unlike both the Messier and NGC lists, Herschel's classes tell you just *what* should be found at the eyepiece; thus 51^4 (or H-IV 51) indicates a planetary nebula, while 32^7 (or H-VII 32) is a compressed cluster of bright and faint stars.

Taking after the popular "Messier club" concept, a number of Herschel groups have been formed in the United States, Canada and England — but have often been short-lived. The biggest stumbling blocks encountered by those who try to work their way through the Herschel list are the inconveniently large number of objects and the faintness of many of them.

Herschel's discoveries were all made with metal mirrored reflectors ranging from 6 to 48 inches in aperture. (His favorite and most useful instrument was his "20 foot" telescope of 18.8 inches diameter.) A good modern 10 or 12 inch reflector should reveal nearly all his finds, if your eye is trained and the sky conditions are excellent. We must remember that despite the size of his instruments, Herschel worked entirely in the climate of England — which was hardly conducive to sky clarity! That he achieved all his discoveries under such adverse conditions should be a true source of inspiration to modern observers.

Looking at the table on page 46, we find that 1,893 of Herschel's discoveries — more than 3/4 the total — lie in classes II and III (faint and very faint

The first object in Sir William Herschel's class V (very large nebulae) is the spiral galaxy NGC-253, located in the constellation Sculptor. One of the largest and brightest galaxies in the sky, it can be seen in binoculars or finderscopes, and is a superb object in telescopes larger than six inches. Lick Observatory photograph.

Classes of Herschel Objects

Class	Number
I. Bright nebulae	288
II. Faint nebulae	909
III. Very faint nebulae	984
IV. Planetary nebulae	78
V. Very large nebulae	52
VI. Very compressed and rich clusters of stars	42
VII. Compressed clusters of bright and faint stars	67
VIII. Coarsely scattered clusters of stars	88
TOTAL	2,508

nebulae). Most of the entries in these two classes prove to be difficult and less interesting deep sky specimens than those in the other classes — especially for observers using smaller instruments.

Based on this, you could form an informal Herschel club with other interested observers, with the goal of viewing the entries in classes I, IV, V, VI, VII and VIII, bypassing entirely those in II and III as unrewarding subjects (at least until you're much more experienced). This gives a total of 615 objects, presenting a much more realistic and achievable objective than attempting to survey the entire catalog.

If you'd like to observe the objects on the Herschel list, you might consider keeping a log — giving the date of each find, instrument used, sky conditions, and a brief description of each object in your own words. Ratings of visual appeal with respect to other objects of the same class (for example, excellent, good, fair or poor) might prove valuable in the future for resurveying the real showpieces or pointing them out to others. You may even wish to do pencil sketches of certain objects, though this often takes time away from contemplative enjoyment of the sights before us at the eyepiece.

Among the 615 proposed Herschel club objects are many superb and unusual sights for even the smallest telescopes. Some were apparently too faint (galaxies) or too small (planetary nebulae) for Messier's rather primitive instruments. Yet in other cases, it's difficult for us to see how he could ever have missed them (the famed Double Cluster in Perseus is just one of many examples of the latter).

We present here a sampling of Herschel objects from around the sky that will hopefully whet your appetite for further exploration of the hidden treasures of his catalog. Many of these have been described in detail in past installments of ASTRONOMY's Star Dome department. Why not begin with this brief list, and then compile your own roster of favorite Herschel objects?

H-V^{18} (NGC-205) is one of two elliptical companions of the famed Andromeda galaxy (M-31), lying in the same field northwest of its nucleus. Messier saw the brighter attendant (M-32 — magnitude 8.7), but didn't number this one (magnitude 9.4). Measuring about 10 by 5 minutes, it can be glimpsed as a soft faint elongated glow in a 2.4 inch refractor at 35 power on a dark night.

H-V^{1} (NGC-253) is a giant spiral in Sculptor, located seven degrees due south of Beta (β) Ceti. It's visible in binoculars and finders despite its low declination. Brighter than ninth magnitude, and 25 by 5 minutes of arc in size, it's one of the finest galaxies in the sky — superb in six inch and larger scopes.

H-VI^{33} and *H-VI*^{34} (NGC-869 and 884) together form the magnificent double cluster in Perseus, visible to the unaided eye and forming a triangle with Delta (δ) and Epsilon (ϵ) Cassiopeiae. NGC-869 is 4.4 magnitude and 36 minutes across; it contains at least 350 stars. NGC-884, 4.7 magnitude and 36 minutes, has over 300 stars. Contrasting star colors are evident in four inch and larger instruments; the outer stars of the clusters overlap.

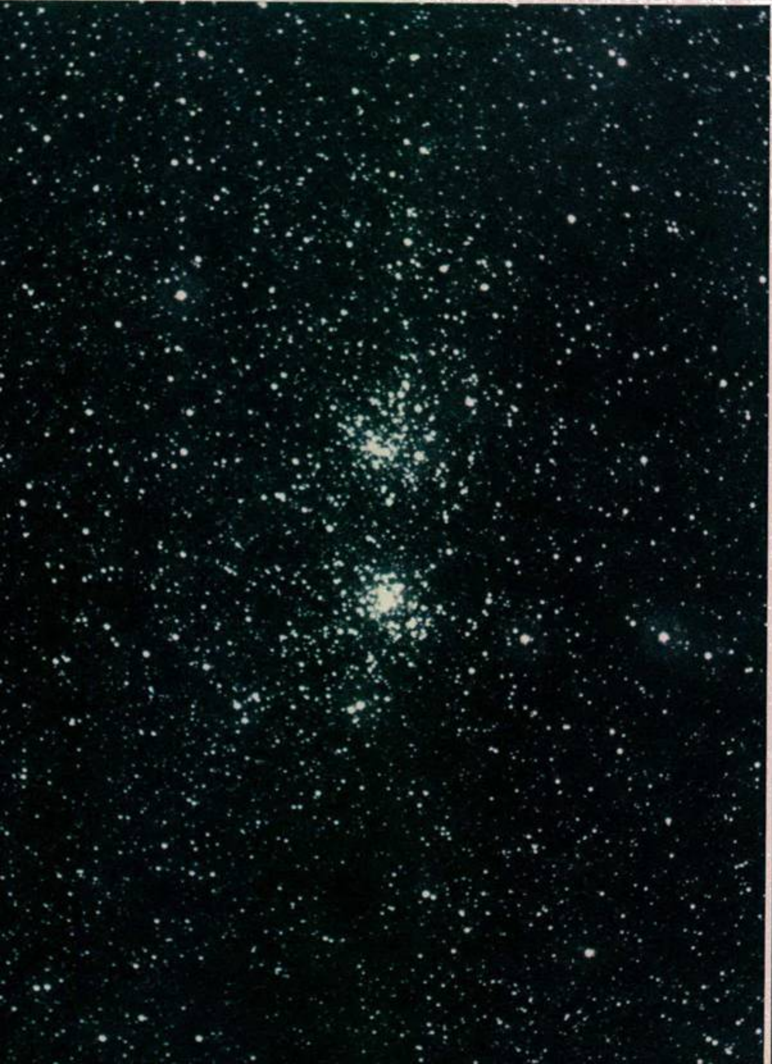
H-IV^{26} (NGC-1535) is a small pale planetary in Eridanus, situated five degrees south of Omicron 1 (o^1)and Omicron 2(o^2), and about four degrees east and slightly north of Gamma (γ). About ninth magnitude, it measures 20 by 17 seconds in size. A faint central star and disk structure are visible in eight inch and larger scopes.

H-IV^{45} (NGC-2392) is a bright planetary nebula in Gemini, located two degrees southeast of Delta (δ). This bluish object is magnitude 8.3 (with a central star), and 47 by 43 seconds of arc in extent. It reminds some observers of a star seen through a dewed eyepiece, or of a telescopic comet. It's easy to spot in three and four inch telescopes; dark structures are visible in 10 and 12 inch scopes.

H-I^{163} (NGC-3115) is a lonely elliptical galaxy in Sextans, seven degrees due south of Alpha (α). It's magnitude is 9.3, and it measures four by one minute in size. In an isolated region, it's rarely observed — even though it's actually better than many of Messier's galaxies. It's easy to spot in a three inch telescope on a dark night.

H-IV^{27} (NGC-3242) is a stunning pale blue planetary nebula in Hydra, two degrees south of Mu (μ). Known as the "Ghost of Jupiter", this ninth magnitude object is at least 40 by 35 seconds in extent. Visible in a 2.4 inch refractor at 70 power, it rivals the Ring nebula (M-57) in Lyra — yet it's seldom observed. The nucleus shows strange variations over the years and should be watched in six inch and larger scopes. It's a real "sleeper" of a deep

Top left: NGC-2392 is number 45 in Herschel's class IV. A planetary nebula — the Eskimo — in the constellation Gemini, it shines at magnitude 8.3. Lick Observatory photograph. Top right: NGC-6992 is part of the Veil nebula in Cygnus; its Herschel designation is V-14. Best seen in richest field telescopes, the Veil is one of Herschel's "very large nebulae". Photograph by Jack Newton. Bottom left: The Double Cluster in Perseus contains the two open clusters NGC-869 and 884, numbers 33 and 34 in Herschel's class VI. Together they form one of the most magnificent sights in the sky. Photograph by Christopher Bowland. Bottom right: *NGC-4565 (Herschel V-24) is an edge-on* galaxy in Coma Berenices. Its distinctive outline is a fascinating sight through the telescope. Photograph by Jack Newton.



Representative Herschel Objects
Listed by Class

Class I — Bright Nebulae

H number	NGC number	Type	Mag.	Size	R.A. (1950)	Dec.	Constellation
200	2683	SG	9.6	8'x1'	$08^{h}50^{m}$	+33°38'	Lynx
205	2841	SG	9.3	6'x2'	$09^{h}19^{m}$	+51°12'	Ursa Major
56	2903	SG	9.1	11'x5'	$09^{h}29^{m}$	+21°44'	Leo
163	3115	EG	9.3	4'x1'	$10^{h}03^{m}$	−07°28'	Sextans
13	3521	SG	9.5	7'x4'	$11^{h}03^{m}$	+00°14'	Leo
65	4361	PN	10.8	81"	$12^{h}22^{m}$	−18°29'	Corvus
43	4594(M-104)	SG	8.7	6'x2'	$12^{h}37^{m}$	−11°21'	Virgo
84	4725	SG	8.9	10'x6'	$12^{h}48^{m}$	+25°46'	Coma Berenices
47	6712	GC	8.9	2'	$18^{h}50^{m}$	−08°47'	Scutum
53	7331	SG	9.7	10'x2'	$22^{h}35^{m}$	+34°10'	Pegasus

Class IV — Planetary Nebulae

H number	NGC number	Type	Mag.	Size	R.A. (1950)	Dec.	Constellation
26	1525	PN	9.3	20"x17"	$04^{h}12^{m}$	−12°52'	Eridanus
45	2392	PN	8.3	47"x43"	$07^{h}26^{m}$	+21°01'	Gemini
64	2440	PN	11.7	54"x20"	$07^{h}40^{m}$	−18°05'	Puppis
27	3242	PN	9.0	40"x35"	$10^{h}22^{m}$	−18°23'	Hydra
50	6229	GC	8.7	1'	$16^{h}46^{m}$	+47°37'	Hercules
11	6369	PN	9.9	28"	$17^{h}26^{m}$	−23°44'	Ophiuchus
37	6543	PN	8.8	22"	$17^{h}59^{m}$	+66°38'	Draco
51	6818	PN	9.9	22"x15"	$19^{h}41^{m}$	−14°17'	Sagittarius
73	6826	PN	8.8	27"x24"	$19^{h}43^{m}$	+50°24'	Cygnus
16	6905	PN	11.9	44"x37"	$20^{h}20^{m}$	+19°57'	Delphinus
1	7009	PN	8.4	44"x26"	$21^{h}01^{m}$	−11°34'	Aquarius
18	7662	PN	8.9	32"x28"	$23^{h}24^{m}$	+42°14'	Andromeda

Class V — Very Large Nebulae

H number	NGC number	Type	Mag.	Size	R.A. (1950)	Dec.	Constellation
18	205	EG	9.4	10'x4'	$00^{h}38^{m}$	+41°25'	Andromeda
1	253	SG	8.9	25'x4'	$00^{h}45^{m}$	−25°34'	Sculptor
28	2024	DN	—	30'x30'	$05^{h}39^{m}$	−01°52'	Orion
44	2403	SG	8.9	17'x10'	$07^{h}32^{m}$	+65°43'	Camelopardalis
24	4565	SG	10.2	14'x1'	$12^{h}34^{m}$	+26°16'	Coma Berenices
42	4631	SG	9.3	13'x1'	$12^{h}40^{m}$	+32°49'	Canes Venatici
15	6960	DN	—	70'x6'	$20^{h}44^{m}$	+30°32'	Cygnus
14	6992	DN	—	78'x8'	$20^{h}54^{m}$	+31°30'	Cygnus

Class VI — Very Compressed and Rich Clusters of Stars

H number	NGC number	Type	Mag.	Size	R.A. (1950)	Dec.	Constellation
20	288	GC	7.2	10'	$00^{h}50^{m}$	−26°52'	Sculptor
31	663	OC	7.1	11'	$01^{h}43^{m}$	+61°01'	Cassiopeia
33	869	OC	4.4	36'	$02^{h}16^{m}$	+56°55'	Perseus
34	884	OC	4.7	36'	$02^{h}19^{m}$	+56°53'	Perseus
22	2548(M-48)	OC	5.3	30'	$08^{h}11^{m}$	− 05°38'	Hydra
9	5466	GC	8.5	5'	$14^{h}03^{m}$	+28°46'	Bootes
40	6171(M-107)	GC	9.2	2'	$16^{h}30^{m}$	−12°57'	Ophiuchus
30	7789	OC	9.6	30'	$23^{h}54^{m}$	+56°26'	Cassiopeia

Class VII — Compressed Clusters of Bright and Faint Stars

H number	NGC number	Type	Mag.	Size	R.A. (1950)	Dec.	Constellation
42	457	OC	7.5	10'	$01^{h}16^{m}$	+58°04'	Cassiopeia
32	752	OC	7.0	45'	$01^{h}55^{m}$	+37°25'	Andromeda
61	1528	OC	6.2	25'	$04^{h}11^{m}$	+51°07'	Perseus
2	2244	OC	6.2	40'	$06^{h}30^{m}$	+04°54'	Monoceros
12	2360	OC	9.5	12'	$07^{h}15^{m}$	−15°33'	Canis Major
17	2362	OC	10.5	6'	$07^{h}17^{m}$	−24°52'	Canis Major
11	2539	OC	8.2	21'	$08^{h}08^{m}$	−12°41'	Puppis
8	6940	OC	8.2	20'	$20^{h}32^{m}$	+28°08'	Vulpecula

Class VIII — Coarsely Scattered Clusters of Stars

H number	NGC number	Type	Mag.	Size	R.A. (1950)	Dec.	Constellation
8	1647	OC	6.3	40'	$04^{h}43^{m}$	+18°59'	Taurus
38	2422	OC	4.5	25'	$07^{h}34^{m}$	−14°22'	Puppis
72	6633	OC	4.9	20'	$18^{h}25^{m}$	+06°32'	Ophiuchus
56	6910	OC	6.7	8'	$20^{h}21^{m}$	+40°37'	Cygnus

OC = Open Cluster
GC = Globular Cluster
PN = Planetary Nebula

DN = Diffuse Nebula
SG = Spiral Galaxy
EG = Elliptical Galax

More Information

The best, readily available reference to the Herschel objects in print today is the reprinted **New General Catalogue**. The volume (also containing both **Index Catalogues**) is available for $10.30 postpaid from the Royal Astronomical Society, Burlington House, London, W1V 0NL, England.

Less useful to "Herschelians" but still a good reference is the **Revised New General Catalogue** by Jack W. Sulentic and William G. Tifft (University of Arizona Press, 1973). This volume retains the original descriptions of the NGC, elaborating on and correcting them where necessary. But it does not indicate the Herschel numbers and classes as does the NGC.

If you'd like to form a Herschel club and need information — or if you belong to one and would like to report your activities — you may write to ASTRONOMY or to James Mullaney, 8647 Old Perry Hwy., Pittsburgh, PA 15237.

sky object; Messier would surely have regretted missing this one!

H-V^{24} (NGC-4565) is a famous, superb edge-on spiral in Coma Berenices, about two degrees due east of 17 Comae. A 10th magnitude sliver of light 14 by 1 minute long, this object is visible in a three inch instrument. A dark rift running lengthwise and cutting it in two, and a nuclear bulge, are both easy to see in six and eight inch scopes on a dark night. This is one of the most fascinating galaxies in the sky; don't bypass it looking for less worthy objects in this crowded region.

H-IV^{37} (NGC-6543) is a bright planetary in Draco, situated roughly midway between Zeta (ζ) and Delta (δ) very near the north pole of the ecliptic. Its luminous pale blue disk looks like a star out of focus and is easy in three and four inch scopes at medium powers — another isolated and neglected object well worth the search! A ninth magnitude object, it is 22 seconds in diameter.

H-IV^{73} (NGC-6826), the "Blinking Planetary" in Cygnus, is found less than a degree east of the easy double star 16 Cygni. It shines at 8.8 magnitude with an 11th magnitude central star, and is 27 by 24 seconds in size. It's so named due to its unusual aspect in the telescope — direct vision shows only the central star while averted vision drowns out the nucleus with bright nebulosity. Alternating back and forth causes an incredible flashing on-and-off effect, and it's one of the few deep sky objects that "does something"! It can be glimpsed in a three inch refractor at 75 power, but the effect becomes ever more striking as aperture increases. (Certain other planetaries exhibit this strange behavior, but not to the degree of this one.)

H-V^{14} and *H-V*^{15} (NGC-6992 and 6960) are the brightest portions of the often pictured Loop or Veil nebulosity in Cygnus. NGC-6960 is centered on 52 Cygni and is known as the Filamentary nebula; 6992 lies about two degrees east and north of 6960. Both are thin curved arcs of faintly glowing gas more than a degree long, and are best seen in richest field telescopes under excellent transparency. We can only wonder how Herschel ever found this extensive nebulosity in his long focus reflectors!

H-IV^{1} (NGC-7009) is the well-known Saturn nebula in Aquarius, located just over a degree west of Nu (ν). This eighth magnitude blue-green egg is a planetary measuring 44 by 26 seconds in size. Its name comes from two thin extensions of the major axis seen on photographs and visible only in large instruments, which give it the aspect of Saturn and its rings seen nearly edge-on. Its intense disk has an eerie cast to it, making it a fascinating object in even the smallest telescopes. After finding this one, it's easy to see why Herschel pressed on to find more!

H-IV^{18} (NGC-7662) is a bright bluish planetary in Andromeda, found 1/3 of the way from Iota (ι) to Omicron (ο), above the Great Square of Pegasus. Shining at ninth magnitude, it measures 32 by 28 seconds and, like most of its kind, can be identified even in a three inch aperture. Strange variations have been reported in its complex nucleus involving the faint central star. Planetaries as a class should be watched for nuclear activity.

H-VI^{30} (NGC-7789) is a ghostly looking open cluster in Cassiopeia, situated midway between Sigma (σ) and Rho (ρ). Glowing softly at magnitude 9.6 and measuring 30 minutes in diameter, this object contains at least 200 suns, making it as rich as the well-known cluster M-11 in Scutum. It can be seen in a 2.4 inch refractor at 35 power, but is easily passed over at first as it blends in with the Milky Way background. In six inch and larger scopes, it is simply superb! The members of this distant stellar commune are remarkably uniform in luster and look like diamond dust against a black velvet sky.

William Herschel was without question the greatest astronomical observer who ever lived. Variously referred to by historians as the "father of modern astronomy", "founder of sidereal astronomy" and "explorer of the heavens", he might also be called the "mentor of amateur astronomers", for he was in the truest sense a backyard astronomer.

Holden, in his biography of the life and works of the great astronomer, said of Herschel's observational model of the Milky Way: "As a scientific conception it is perhaps the grandest that has ever entered into the human mind." He continued: "As a practical astronomer he remains without an equal. In profound philosophy he has few superiors. By a kindly chance he can be claimed as the citizen of no one country. In very truth his is one of the few names which belong to the whole world."

Let's retrace the glorious pathway in the sky left by this great and ardent observer!

Houghton Mifflin launches introductions for nonmajors.

FIELD
VERSCHUUR
PONNAMPERUMA
from the big bang to the primordial soup

COSMIC EVOLUTION
An Introduction to Astronomy
George B. Field
Harvard College Observatory
Gerritt L. Verschuur
University of Colorado, Boulder
Cyril Ponnamperuma
University of Maryland, College Park
About 528 pages • Early 1978

Using cosmic evolution as an organizing theme, Field, Verschuur, and Ponnamperuma give students a dramatic introduction to astronomy. Their vivid writing style engages and motivates students, and they support theories with the most up-to-date evidence available. Chapter summaries, end-of-chapter review questions, vocabulary lists, and in-depth thought questions provide plenty of review, reinforcement, and assessment opportunities.

SHIPMAN
the contemporary survey

THE RESTLESS UNIVERSE
An Introduction to Astronomy
Harry L. Shipman
University of Delaware, Newark
About 384 pages • Instructor's Manual
Early 1978

Shipman confronts the complex technical concepts of astronomy head-on, but does so with words instead of equations. Using concrete examples, he clearly illustrates the physical properties organizing the universe. From an introductory chapter on the history of astronomy, through the solar system, the galaxy, and up to a final speculative chapter on cosomology, Shipman offers a succinct survey of astronomy with well-developed pedagogy.

three new
to astronomy

SWIHART
clear as optical glass

JOURNEY THROUGH THE UNIVERSE
An Introduction to Astronomy
Thomas L. Swihart
University of Arizona, Steward Observatory
About 384 pages • Instructor's Manual
Early 1978

Swihart's brilliant use of analogy makes even the most sophisticated concepts clear and precise to nonmajors. Though the quantitative nature of astronomy is de-emphasized, the coverage is complete and correct. High readability and emphasis on descriptive astronomy make Swihart's **Journey Through the Universe** a smooth trip for a broad range of students.

To request examination copies of the books or for more information on the films, contact your regional Houghton Mifflin sales office.

Houghton Mifflin

Dallas, TX 75235 • Geneva, IL 60134 • Hopewell, NJ 08525 • Palo Alto, CA 94304 • Boston, MA 02107

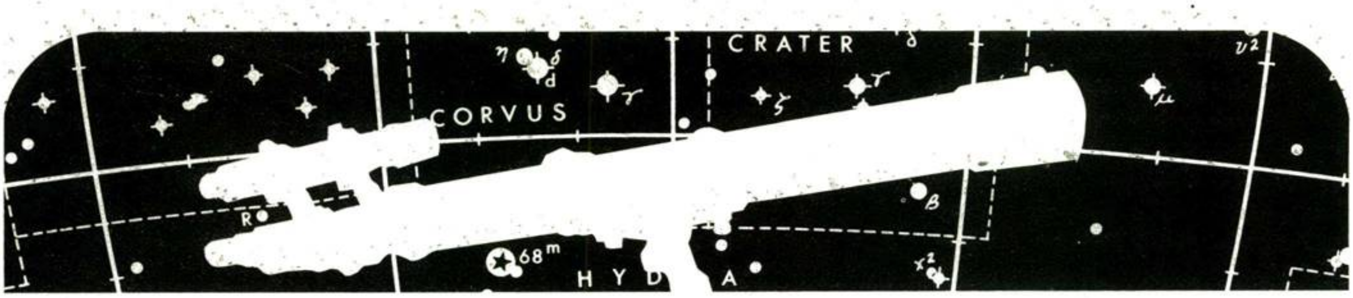
Or if you gravitate to the visually dramatic —

EXPLORATIONS IN SPACE AND TIME
A Series of Computer-Generated Astronomy Films
by M. L. Meeks, Haystack Observatory
Massachusetts Institute of Technology
and Harvard University
Eight 16mm color films with commentary or twelve 8mm silent color film cartridges, both with Film Notes • 1973

By using a computer, the Smithsonian Star Catalogue, exponential zooms, dramatic alterations of time and distance scales, and the illusion of three dimensions created by rotations, the Meeks films illuminate astronomical phenomena as conventional models cannot.

Campbell/Ballou
FORM AND STYLE
Theses, Reports, Term Papers
Fifth Edition
William Giles Campbell
Stephen Vaughan Ballou
California State University, Fresno
About 192 pages • paper • spiralbound
Early 1978

This highly successful guide to preparing research papers, formal reports, and theses now offers even more facsimile examples of all forms of usage and up-to-date format specifications. Conveniently cross-referenced, Campbell/Ballou provides detailed instructions for writing footnotes in the three most widely accepted styles and for typing all the elements of a paper.



EQUIPMENT ATLAS

Building A 6" Reflector
Part 5: Two Mountings You Can Build at Home

by
Richard Berry

If you build your own telescope, you'll eventually face the problem of mounting it so that you can aim it at celestial objects you want to see. There are plenty of sources for descriptions of telescope mountings — you need only check your public library (especially if you live in a larger city). But these descriptions can be discouraging if you don't own a lathe, haven't got the foggiest notion how to find scrap in a metal yard at bargain prices, or lack the means to get a welder or machinist to do a fancy job for you. Commercial mountings (covered in Part 4, September 1977) are expensive, so perhaps you just can't afford one.

The two mountings we'll describe this month are designed to help you if you've got those "telescope mounting blues". Nothing fancy is needed to build them: a hand saw, hand drill, screwdriver and a hammer — and some sandpaper and a paintbrush to spruce up the finished product. You'll find everything you'll need at your local hardware store, or lumber and home products store. Each design is very versatile: You can change the dimensions to suit your particular needs, substitute materials, or substitute parts if you know of a hardware store with an unusually good stock of useful but hard-to-find items. If you do own machine tools, you can make sweeping revisions in these plans if you want to. Whatever you do, though, remember that the important thing is to get out under the night sky and explore!

Altazimuth Mountings

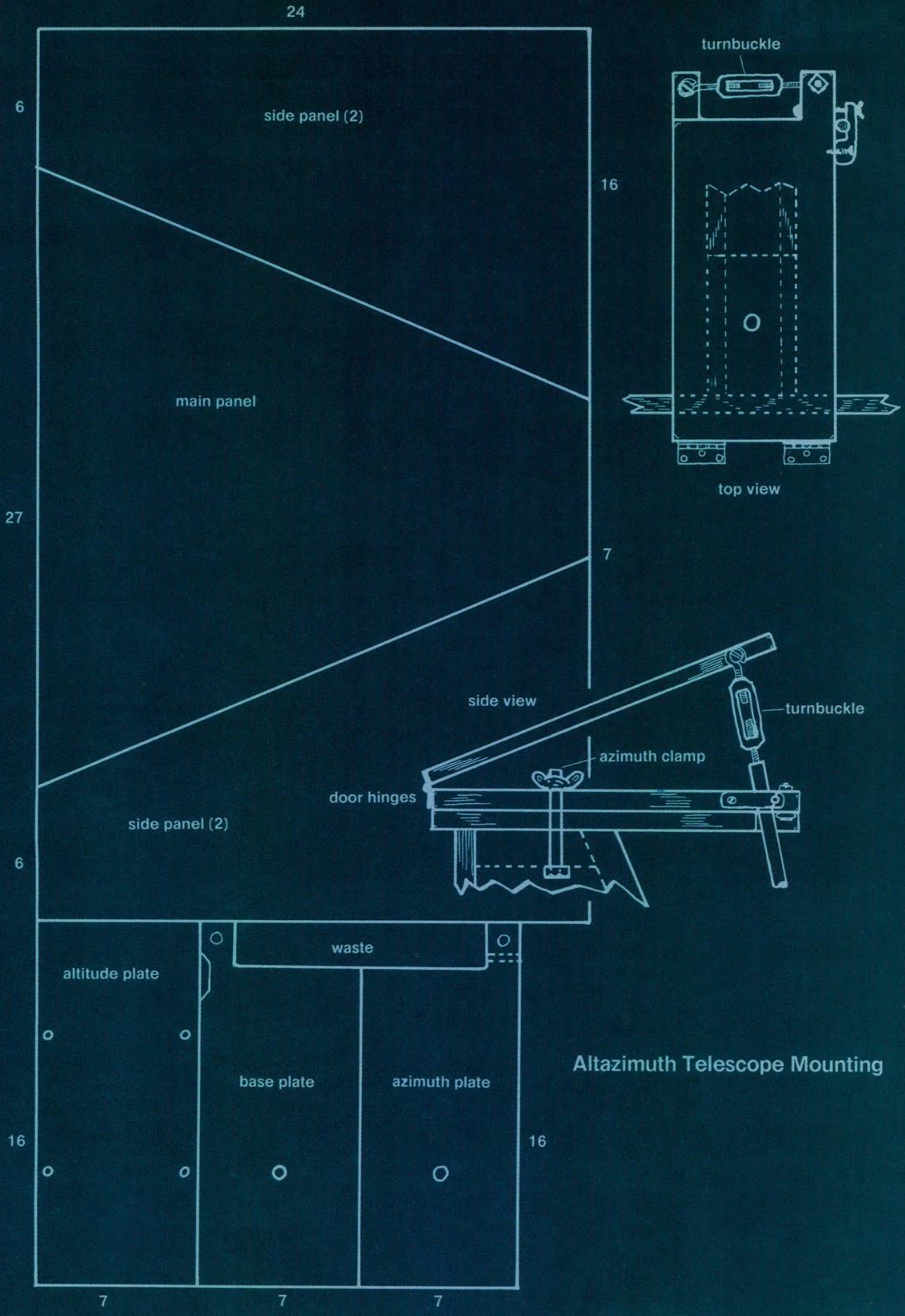
Altazimuth mountings have a strong historical tradition: Great observers of the past often used altazimuth mounted telescopes because of their incredible simplicity. William Herschel discovered Uranus with an altazimuth mounted six inch reflector, and even his great 48 inch reflector was an altazimuth. For the modern observer, an altazimuth mounting is an easy way to start with a telescope you've made yourself. Altazimuth mountings offer up-down and left-right motions — there is no simple one axis way to track stars — and an alt-az (as they're sometimes called) doesn't have to be balanced or counterweighted to work well, so the finished instrument weighs less. Use of an altazimuth is easy to understand if you're just starting to use a telescope, and it's also a good first mounting for your telescope. You can build a fancier equatorial later.

The first step in building an altazimuth mounting is to take a look at pictures and plans. The base is a tripod with a new look. It is easy to cut and assemble because there are no compound angles in it — just two boards with tabs at one end. For coarse motion, you simply loosen the clamp and swing the telescope to the approximate right direction. Tighten it, and then center the object using the azimuth turnbuckle for a slow motion. For altitude, just clamp the altitude rod near the bottom. All you have to do is loosen the clamp and move the telescope to the proper altitude. Fine motion is provided by the turnbuckle. A second altitude rod balances the first for extra stability.

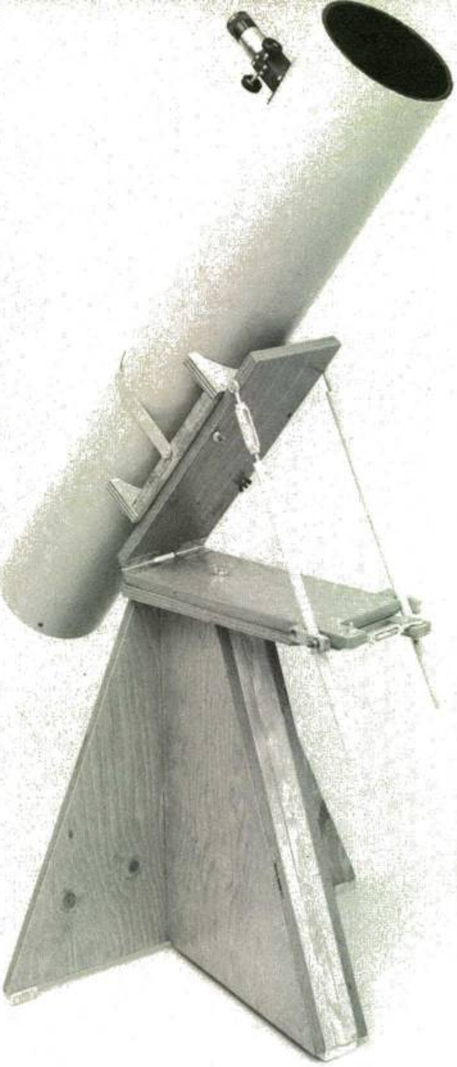
Finding objects is fast and efficient with this mounting. You'll learn quickly the "feel" of the controls so you won't have to look at them while pointing the telescope. At 150 power, its stability leaves little to be desired, but at 300 power, operating the controls causes moderate image bouncing. Since most observations are carried out at relatively low powers, this mounting should prove satisfactory for every beginning telescope user.

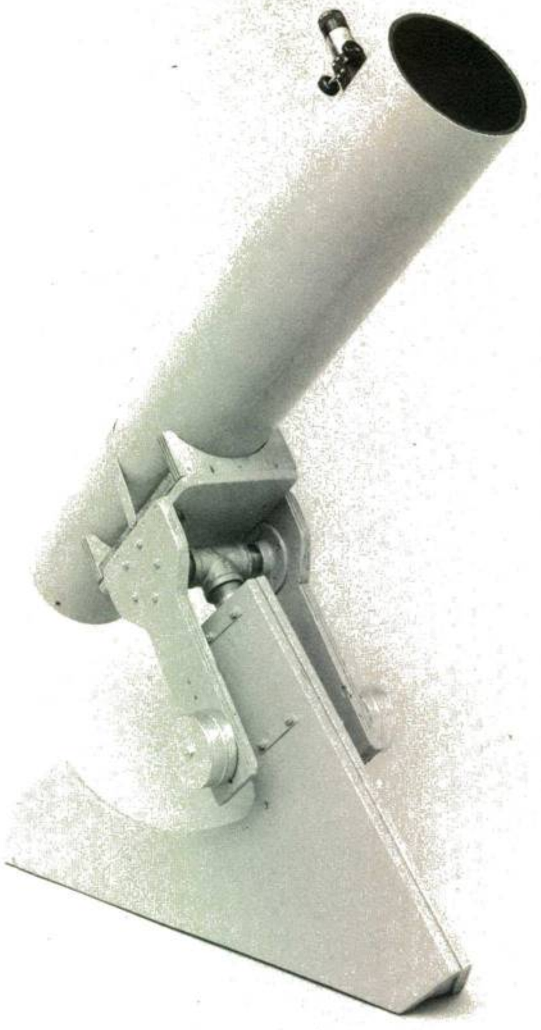
The tripod can be altered to be almost any height, and it can be built from lighter material than 3/4 inch plywood; 3/8 inch would do for a "very portable" mount, or you could cut holes to leave a lightweight latticework tripod. Rather than assemble it with glue, nails and screws, you can use bolts so that you can disassemble it for carrying as flat pieces of wood. Whatever you decide to do, though, you can do it without power tools.

You should feel free to use your imagination on


24
6
side panel (2)
16
main panel
27
7
side panel (2)
6
turnbuckle
top view
side view
turnbuckle
azimuth clamp
door hinges
waste
altitude plate
base plate
azimuth plate
16
16
7
7
7

Altazimuth Telescope Mounting





Left: This little altazimuth mounting is great for your first telescope and doesn't take lots of time and effort to build — two evenings plus a few hours painting or varnishing, and you should be ready to go! Right: The equatorial takes a bit more work, but still shouldn't cost you much over $25 — about $10 for the pipe, $9 for plywood (half a full sheet of 3/4 inch), $3 to $4 for the hardware, and a few more for paint and brush.

the specific hardware you buy for your mount's moving parts: There may be a completely preassembled window closing mechanism available in some hardware stores that might replace the clamp, dowel and turnbuckle device shown on the mounting. You may think of a different way to attach the hinges, or perhaps you'll run across some knobs that'll work rather than the suggested wingnuts. And, within reason, you can alter any dimension you want to.

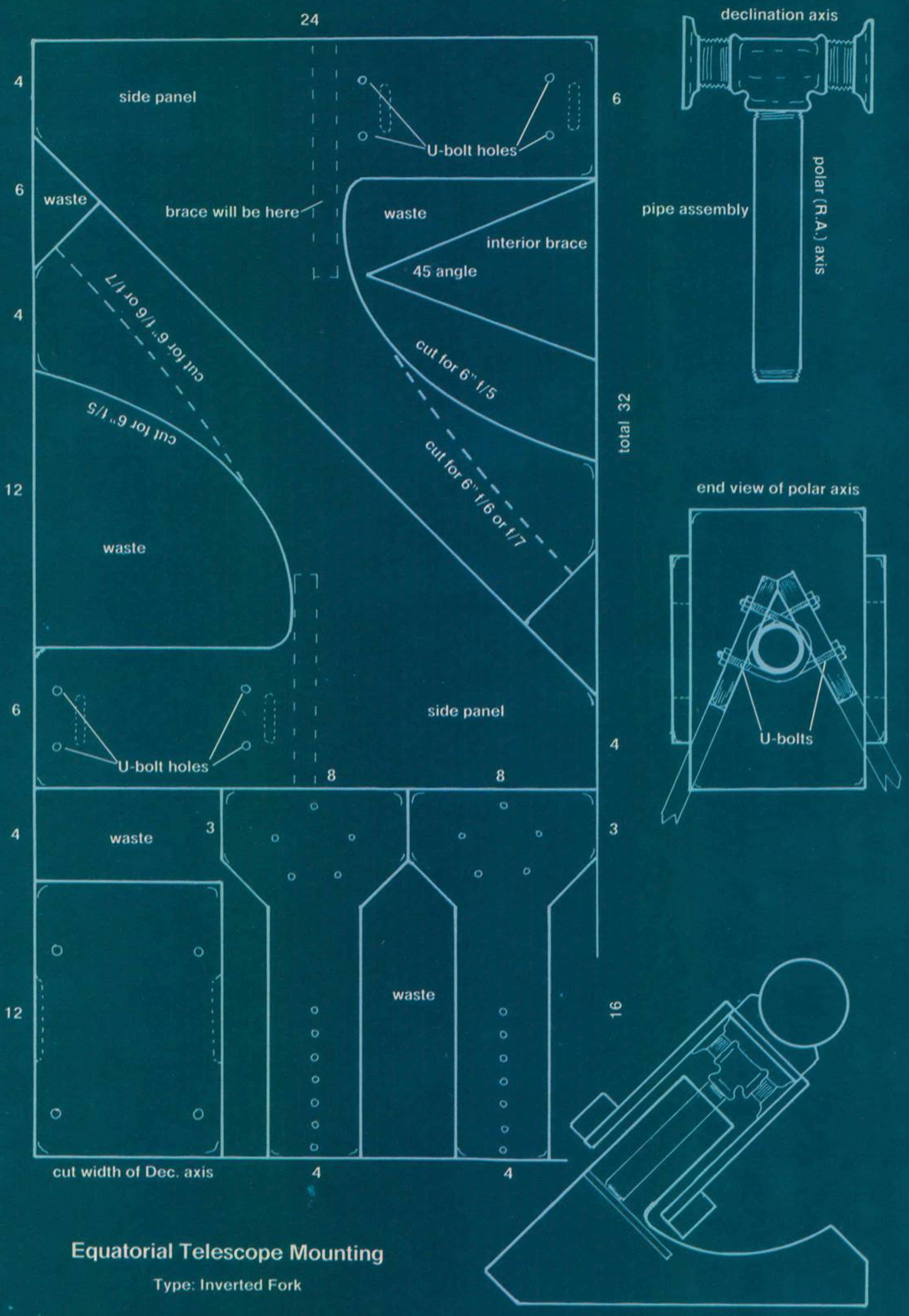
Finishing is your preference too. You needn't do anything after cutting the pieces, or you may opt to sand, stain and varnish the wooden parts. You can paint it bright colors, add your personal insignia, eyepiece racks — or whatever else you feel like.

Equatorial Mountings

There are so many plans for equatorials, as well as articles offering conflicting advice, that beginners can hardly know what to do. The best way to start with an equatorial is *without* setting circles and clock drive. Learn the constellations and how to find your way around the sky by eye first. Get to know where to point your telescope using only a star chart. You'll enjoy these hours spent under the stars.

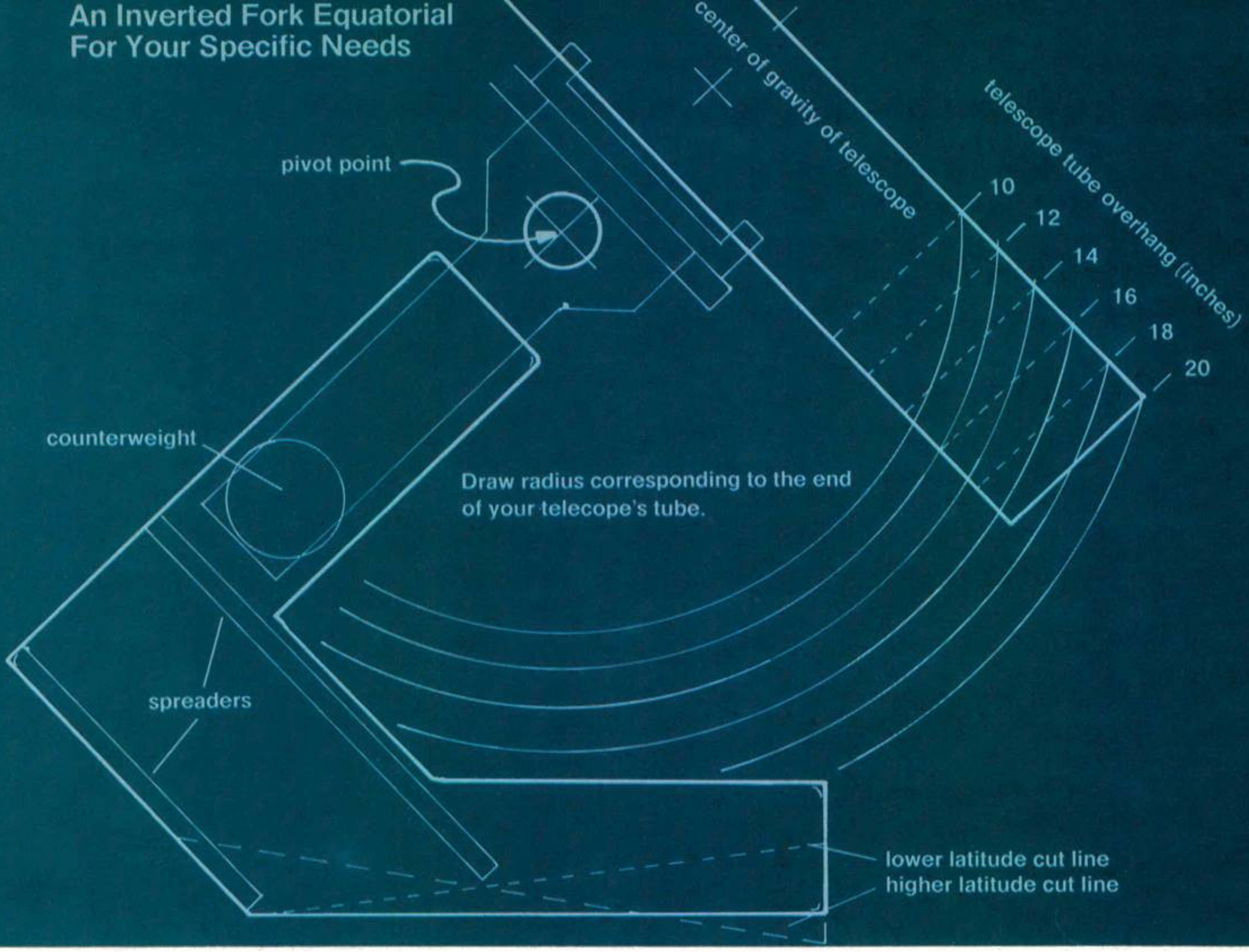
The equatorial mount we built is an unusual type called an *inverted fork* mounting. Like classical German mountings made from pipe, this equatorial uses readily available pipe parts. Unlike them, it can swing freely across the meridian without hitting the pier. It has no right ascension counterweight cast from lead — a very messy operation at best. Instead, you'll need a declination counterweight which can be made from any heavy material.

Your first decision will be the size pipe you want to use. For "ordinary" performance, use 1-1/2 inch pipe for a 6 inch telescope, 2 inch for an 8 inch, and 2-1/2 inch for a 10 inch. For "best" performance, use heavier pipe; ask for heavy-wall 2 inch pipe for a 6 inch, and 2-1/2 inch for an 8 inch. Larger telescopes can be mounted on pipe mountings, but generally it's worth the extra trouble and expense to do a more "professional" job. Hardware stores usually have 1-1/2 inch and 2 inch pipe, but you'll have to go to a plumbing store to find larger sizes. If you have a choice between malleable iron and galvanized pipefittings, remember that galvanized ones will not rust and are therefore preferable.


24
4
side panel
6
U-bolt holes
6
waste
brace will be here
waste
interior brace
45 angle
4
cut for 6" f/6 or f/7
cut for 6" f/5
cut for 6" f/5
cut for 6" f/6 or f/7
total 32
12
waste
6
U-bolt holes
side panel
4
8
8
4
waste
3
3
12
waste
16
cut width of Dec. axis
4
4
declination axis
pipe assembly
polar (R.A.) axis
end view of polar axis
U-bolts

Equatorial Telescope Mounting

Type: Inverted Fork



An Inverted Fork Equatorial For Your Specific Needs

center of gravity of telescope
telescope tube overhang (inches)
10
12
14
16
18
20
pivot point
counterweight
Draw radius corresponding to the end of your telecope's tube.
spreaders
lower latitude cut line
higher latitude cut line

Since the telescope will turn on the pipe threads themselves, your first concern is that the pipe threads be as smooth acting as possible. One good way to smooth them is a process called lapping, in which a fine abrasive (carborundum left over from making the telescope mirror) is run between the mating surfaces. Using kerosene, rinse off any grease already on the threads; then coat them with a #600 carborundum mixed with oil. Run the threads together as far as they will go, and then out again. Keep running them together until their motion becomes smooth and you can make one to two turns more than you originally could. Thoroughly rinse the abrasive mixture off with a solvent such as paint thinner. Lapping the threads will probably take about 10 minutes, and can be done — if necessary — after you've finished the rest of your mount.

Once again, this tripod is unusual. While you can make all sorts of nice looking three-legged tripods, they always involve tricky angle cuts. This one requires only flat pieces. The wood and the pipe are joined by U-bolts. You may have some trouble finding the right size U-bolts in poorly stocked hardware stores, but most will have an adequate selection for your needs.

Cut the parts according to plan; drill, sand, and assemble them with nails. Then check that your polar axis angle is within a few degrees of the value for your latitude. If it isn't, trim material off the bottom of the base pieces. Once the angle is correct, reassemble using glue and wood screws. You can finish the parts any way you wish. The mounting shown was painted with wood primer, followed by two coats of enamel.

The declination counterweights can be made of anything that's fairly heavy — bricks or flat scraps of steel work rather well. The flat sides of the fork are easy to bolt all sorts of heavy stuff to. The tripod lends itself to adding racks for eyepieces and miscellaneous observing equipment because there's lots of space inside it.

This equatorial has neither drive nor slow motion because you'll find you really don't need them much when you're just starting out, or when you're looking for Messier objects, examining the moon, or splitting a few close doubles.

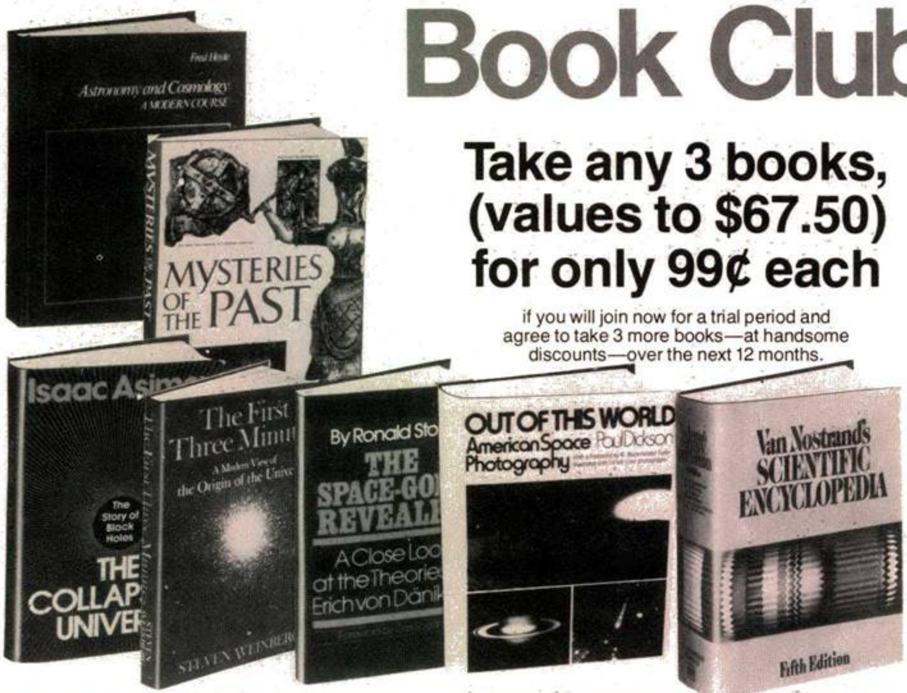
However, if you want to try piggybacking your camera for astrophotography, you'll need some way to track the stars. On page 54 is an alternate design that lets you track by hand for about 20 minutes — long enough to reach the sky fog limit just about anywhere with modern cameras and films.

Editors' Note: If you have built a telescope mounting that works well, let us know about it! Be sure to include pictures that show exactly how it works, and a thorough description of how to put it together.

From Copernicus to the radio astronomers... from the Red Planet to quasars...

discover the great books—and great values—
you get as a member of the

Natural Science Book Club



Take any 3 books, (values to $67.50) for only 99¢ each

if you will join now for a trial period and agree to take 3 more books—at handsome discounts—over the next 12 months.

(Publishers' Prices shown)

61660. MECHANICS OF THE MIND. *Colin Blakemore*. Reports discoveries now being made about the human brain: why we have an awareness of self, how we feel and see the world we live in, why we sleep, how we remember. 200 beautiful photographs and drawings. **$19.95**

36395. BLACK HOLES, QUASARS AND THE UNIVERSE. *Henry L. Shipman*. Absorbing exploration of the frontiers of astronomy. **$12.95**

55000. THE ILLUSTRATED ENCYCLOPEDIA OF ASTRONOMY AND SPACE. One-volume encyclopedia covers the full range of astronomical knowledge and space exploration. **$16.95**

42575. THE DRAGONS OF EDEN. *Carl Sagan*. Breathtaking overview from prehistory to the present explains how human beings evolved, how our brains work, and why other intelligent beings may try to communicate with us. **$8.95**

34670. ASTRONOMY AND COSMOLOGY. *Sir Fred Hoyle*. 700-page survey of the ideas, principles, and processes of astronomy by one of the world's finest astronomer-cosmologists. **$16.50**

39560. COLONIES IN SPACE. *T. A. Heppenheimer.* Examines how towns will be laid out; how food, water and air will be supplied; what is being planned for future interstellar flight. 100 illustrations. **$12.95**

34665. ASTRONOMY: Fundamentals and Frontiers. Third Edition. *Robert Jastrow and Malcolm Thompson*. Extraordinary tour of modern astronomy. Includes data gathered by Apollo and Mariner probes and over 330 illustrations—many in color. **$15.50**

57067. THE KEY TO THE UNIVERSE: A Report on the New Physics. *Nigel Calder.* Highlights in simple, direct language the latest developments in high-energy physics and astronomy that are revealing the most puzzling secrets of the universe. Richly illustrated. **$14.95**

48475. FIELDBOOK OF NATURAL HISTORY. *E. Laurence Palmer and H. Seymour Fowler.* The most authoritative and comprehensive guide to natural history available. With over 800 illustrations, it explores all major plant and animal species and most rocks and minerals. **$17.50**

00470. VAN NOSTRAND'S SCIENTIFIC ENCYCLOPEDIA. *Edited by Douglas M. Considine*. Nearly 200 experts have contributed to the thoroughly revised and expanded Fifth Edition of the most authoritative single-volume source of scientific information ever assembled. Over 2,500 illustrations. *Counts as 3 of your 3 books.* **$67.50**

49340. FUNDAMENTAL ASTRONOMY. *Franklyn W. Cole*. Provocative work traces our intellectual assault on the mysteries of the universe from man's earliest sensory-oriented glimmerings to the very frontiers of modern astronomical thought. **$16.50**

82775. TEN FACES OF THE UNIVERSE. *Sir Fred Hoyle*. Noted British astronomer offers a personal view of the universe as seen through the eyes of the mathematician, the physicist, biologist, and everyman. Handsomely illustrated. **$10.95**

35740. THE BEGINNER'S GUIDE TO THE SKIES. *C. H. Cleminshaw.* A month-by-month handbook invites you to tour the night sky through more than 100 easy-to-follow line drawings, charts, and tables. **$7.95**

MEMBERSHIP BENEFITS • In addition to getting three books for 99¢ each when you join, you keep saving substantially on the books you buy. • If you continue membership past the trial period, you will be eligible for our Bonus Book Plan, with savings of at least 70% off publishers' prices. • At 3-4 week intervals (15 times per year) you will receive the Book Club **News,** describing the coming Main Selection and Alternate Selections, together with a dated reply card. In addition, up to 4 times a year, you may receive offers of special selections, always at substantial discounts. • If you want the Main Selection, do nothing and it will be sent to you automatically. • If you prefer another selection, or no book at all, simply indicate your choice on the card, and return it by the date specified. • You will have at least 10 days to decide. If because of late mail delivery of the **News,** you should receive a book you do not want, we guarantee return postage.

63350. MYSTERIES OF THE MEXICAN PYRAMIDS. *Peter Tompkins*. Absorbing investigation of the arcane civilizations of ancient Mexico. Lavishly illustrated. **$20.00**

87051. WHITE HOLES. *John Gribbin*. Fascinating speculation on the cosmic gushers which may be the starting point of all matter in the universe. **$8.95**

79705. THE SPACE-GODS REVEALED: A Closer Look at the Theories of Erich von Daniken. Critical assessment separates fact from fiction. **$7.95**

85461. UNTIL THE SUN DIES. *Robert Jastrow.* Examines the meaning of the latest discoveries in astronomy, space exploration, and the origin of life, and describes forces that have shaped the human race and created the power of human intelligence. **$8.95**

63340. MYSTERIES OF THE PAST. Beautifully illustrated volume explores the riddles of past civilizations. Totally absorbing reading. *Counts as 2 of your 3 books.* **$34.95**

37211. THE CAMBRIDGE ENCYCLOPAEDIA OF ASTRONOMY. Huge, definitive work covers everything from the life and death cycles of the stars to the origin and fate of the cosmos. Hundreds of photographs, charts and drawings. *Counts as 2 of your 3 books:* **$35.00**

86760. WHAT IS THE WORLD MADE OF? *Gerald Feinberg*. A layman's introduction to the fascinating world of particle physics, using a non-mathematical approach that provides a lucid explanation of subatomic phenomena. **$10.00**

66545. OUT OF THIS WORLD: *Paul Dickson*. 200 of the most spectacular photographs ever returned to earth have been collected in this first fully illustrated survey of American space photography. **$19.95**

48601. THE FIRST THREE MINUTES/THE COLLAPSING UNIVERSE. First, a particle physicist analyzes the first few minutes following the Big Bang. Then Isaac Asimov investigates such frontiers of astronomy as black holes, pulsars, and quasars. *The 2 count as one book.* **$17.90**

Natural Science Book Club 4-A1A
Riverside, New Jersey 08075

Please accept my application for membership and send me the three volumes indicated, billing me only 99¢ each. I agree to purchase at least three additional Selections or Alternates during the first 12 months I am a member, under the club plan described in this ad. Savings range up to 30% and occasionally even more. My membership is cancelable any time after I buy these three books. A shipping and handling charge is added to all shipments.

3 books for 99¢ each.
Indicate by number the 3 books you want.

☐ ☐ ☐

A few expensive books (noted in book descriptions) count as 2 or 3 choices.

Name ____________________

Address ____________________

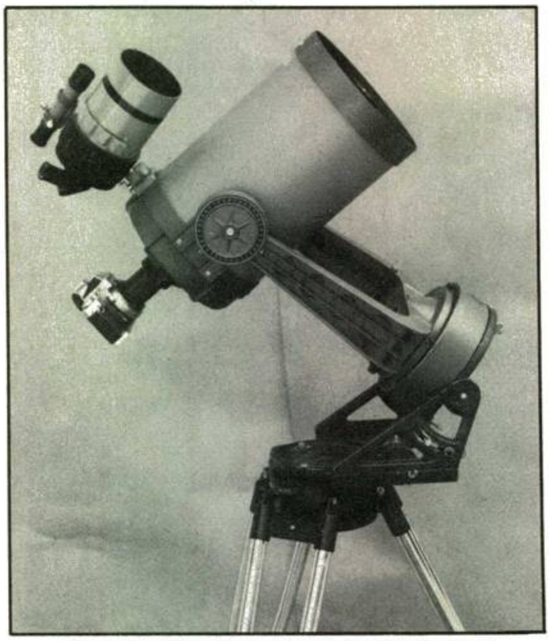
City ____________ State ________ Zip ________

(Offer good in Continental U.S. and Canada only. Prices slightly higher in Canada.)

HEADQUARTERS FOR CELESTRON© TELESCOPES

Buy the NEW CELESTRON 90 Guide/Telescope and get our OMNI-AXIS MOUNT FREE

No compromise in quality with this NEW 3.55" CELESTRON MAKSUTOV. It adds a new dimension to astrophotography. Because the Celestron 90 is so small (only 8" long) it is very stable. It will fit any Celestron telescope as well as other types. Can be used with our Electronic Eyeball* for automatic guiding in R.A. The Celestron 90 comes with our FREE OMNI-AXIS MOUNT which lets you quickly select any guide star within 10 degrees of the object you wish to photograph. This new scope comes complete with finder, eyepiece, diagonal, a 2.5x Barlow and a convenient carrying case.

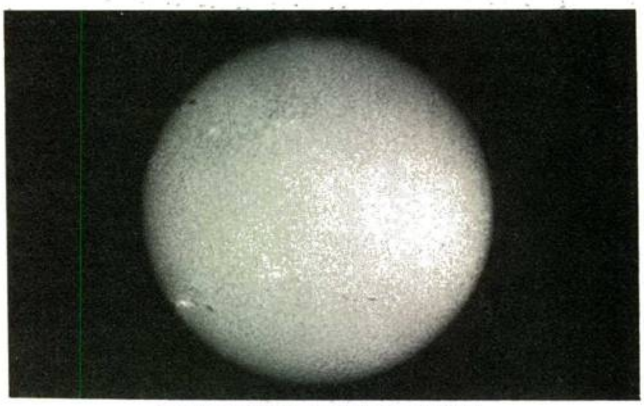


Celestron 90 Guide scope and Omni-Axis mount
Complete $295.

Recognized As Headquarters For Telescope Solar Filters

Solar-Skreen® Sun Filter

Blocks all heat before it enters your scope. Fits any size scope of any type. U. S. Patent No. 3,897,140. GUARANTEED SAFE: Thousands in use throughout the world by amateurs and professionals. No glue or magnets used. From $14.



DAYSTAR*FILTER PHOTOGRAPH

Hydrogen-Alpha Filters

SOLAR PROMINENCE PROBE*: 3 to 4 angstrom half-bandwidth. For prominences only. From $178.

DAYSTAR* Hydrogen-alpha filter: 0.75 angstrom half-bandwidth. See prominences and solar disk detail. From $895.

ASK ABOUT OUR COMET AWARD PROGRAM

We honor Master Charge and BankAmericard

Money-Back Guarantee on all products we sell.

ROGER W. TUTHILL, INC. Box 1086 A, 11 Tanglewood Lane, Mountainside, N.J. 07092
Telephone 201-232-1786

*Trade Mark

STRAIGHT TALK ABOUT EYEPIECES

Of course no eyepieces are perfect in every respect BUT eyepieces are the final key to good telescope optical performance. We offer the following eyepiece choices:

Kellners $16. ea.
Orthoscopics $23. ea.
Erfles $28. ea.
Brandons $55. ea.
and
Clavé Plossls $61.00 ea.

These eyepieces span the viewing requirements of the casual observer to the most demanding professional. Write for a copy of an independent users report #Z-1000 for a detailed discussion of the essential points of comparison on these critical elements contributing to your astronomical enjoyment and satisfaction.

TRAP A STAR
with
NEW
STAR—TRAP™
illuminated reticle eyepiece

IDEAL FOR ALL FINDERS OR GUIDE SCOPES

- Self-contained switch and replaceable 6-volt battery
- Dual red light-emitting diodes (10-year life)
- Matching molybdenum cross hairs
- Adjustable brightness and focus
- Rubber eyecup
- Only 8 ounces

Model No. 1 — 27 mm. Kellner eyepiece	**$46.**
Model No. 2 — 20.5 mm. Kellner eyepiece	**$48.**

Attention Dynamax Owners

Custom Engineered Accessories for your scope to improve its operation

- Finger-tip latitude adjuster for New Criterion field tripod.
- Slow motion manual Declination adjustment - 5 times finer than original adjustments on older models.
- Velvet touch helical focuser-overcomes mirror image shift during focusing, when present.
- No Du*Caps reduce dewing to improve viewing.
- 7x50 right angle variable power finder - wider fields and brighter views. Takes standard eyepieces.
- Precision Polar Axis Finder makes lining up on the Celestial Pole a snap.
- Tele-Compressor reduces photographic time on deep sky objects.
- Solar Skreen* and Luna Shade* filters and Cells.

AN ARRAY OF GREAT PRODUCTS
To Make Your Hobby More Enjoyable

THE STEREOOCULAR* ON A CELESTRON® 8

Lets you look naturally and restfully with two eyes. Gives great views of moon and planets. Some even claim to see a 3-dimensional effect.

Fits 1-1/4" drawtubes on refractors or Cassegrain-type scopes. Used with matched eyepieces. Two persons can use at the same time.

Still only $249.

PRECISION POLAR AXIS FINDER*

Get perfect celestial pole alignment quickly and easily every time. When the centered 4x cross hairs are set directly on Polaris, the 0.8-degree offset barrel points precisely on the pole. Novel Polaris date and time chart supplied FREE.

Celestron model 5 or 8	**$63.**
German Equatorial model	**$57.**

Shown Right **Patent Applied For**

NOTICE: We are now able to supply all your telescopic needs with CELESTRON Schmidt-Cassegrains, EDMUND SCIENTIFIC reflectors; our own RFT units and custom accessories for DYNAMAX scopes of all sizes. Ask about our FREE SOLAR-SKREEN* offer concerning these products. In addition, we can supply your needs for BRANDON eyepieces, STAR-TRAP* eyepieces, LUNA-SHADE* filters, 12v D.C. inverters, ELECTRONIC EYEBALL* guiders, SUPER STAR-TRAP* DRIVE CORRECTORS, CELESTRON binoculars, and many other items. Send now for our FREE catalog.

ROGER W. TUTHILL, INC.
Box 1086A, 11 Tanglewood Lane, Mountainside, NJ 07092

ASTRONOMY

Index to Volume 4, 1976

ASTRONOMY's cumulative Index to Volme 4, 1976 is now available. This subject index covers the months of January through December 1976 (issue Nos. 1 through 12) in an expanded format, making it a valuable addition to your home library!

Index to Volume 4 is available for $1.25 each, plus 25¢ per order for postage and handling.

22 1/2"
22 1/2"
SLITFRAME
60 1/2"
67 1/4"
140 1/4"
DOME SKIRT
SHUTTERS OPEN
30"
115"
76 1/4
SIDE VIEW WITH OPTIONAL BASE
SHUTTERS CLOSED

A NEW STAR.

Observa-DOME Silver Series.

Observa-DOME, the world's most experienced manufacturer of Observatory Systems, has developed its new SILVER SERIES utilizing skills and techniques gained from 25 years of building more professional observatory structures than anyone else!

The affordable SILVER SERIES incorporates all the "most wanted" features which astronomers, both amateur and professional, have demanded! Overwhelming acceptance of our Two-Meter Silver Series Observa-DOME has led to our latest Three-Meter design with other larger Silver Series Observa-DOMES to come.

"Do-it-yourself" Components

For the very first time "difficult to fabricate" components of the Observa-DOME Silver Series Two and Three-Meter Models are available for those willing to make their subassemblies according to our detailed drawings, instructions and material lists. This new program is designed to make your individual or group observatory project a complete success.

Exclusive sales agency in USA & Canada for the incomparable ZEISS Planetarium.

I am interested in information on an Observa-DOME of:
☐ 2 MTR., ☐ 3 MTR., ☐ Complete ☐ Components or
________ diameter Observa-DOME.

Name ________
Address ________
City ________ State/Prov. ________ Zip ________

Observa-DOME
LABORATORIES, INC.
P.O. Box 885
Jackson, Mississippi 39205

The Astroscan 2001 — a major breakthrough in
Edmund Scientific Company's 35-year commitment to astronomy.

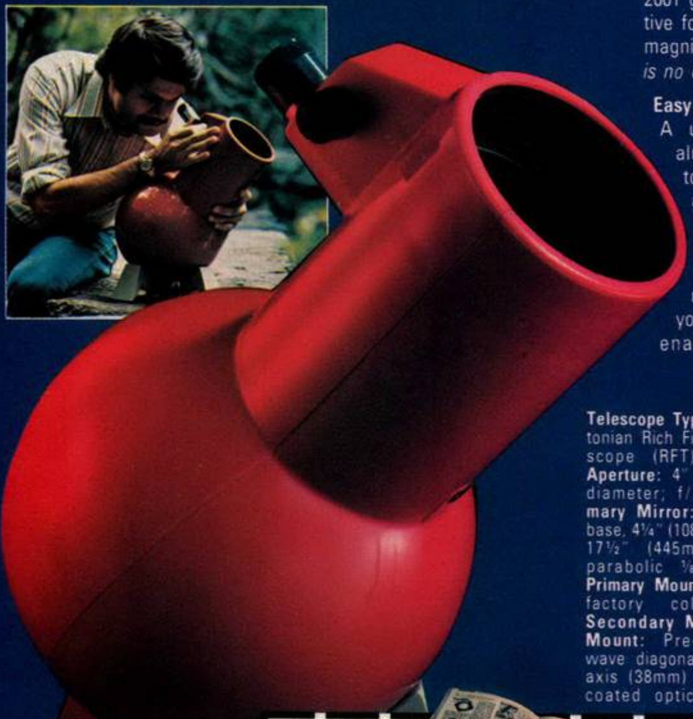
Now, An Affordable Rich Field Telescope Rivaling Any Instrument You May Have Used.

The Edmund Astroscan 2001 is a unique instrument created to provide compact and convenient portability without sacrificing the quality optics required for effective and satisfying astronomical viewing. And, at just $149.95, it represents the telescope bargain of the decade!

The 2001 is a classic Newtonian reflector telescope system enclosed in a high-impact plastic body which is both practical and eye-catching. Its optical system provides the clearest, brightest, most spectacular wide-angle views of the heavens you've ever seen. The fully coated optics in the Astroscan 2001 are comparable to those used in professional telescopes. Extreme simplicity of design, the result of months of sophisticated engineering and testing, enables you to take this fine instrument anywhere and use it almost instantly.

Wide Field View Shows You More

The Edmund Astroscan 2001, a true "wide field" telescope, provides a giant 3° field of view with a resolution you'll find hard to believe in an instrument this inexpensive. You'll see more stars in a single view with greater clarity, with greater ease than you've ever thought possible.



Take It Anywhere — Use It Anywhere!

The 2001 weighs just over 10 pounds and is only 17 inches long. It can set up in seconds. Anyone, even a young child, can use it easily.

Its 4¼" diameter parabolic primary mirror is precision polished to a tolerance of ⅛ wave. A ⅛ wave diagonal mirror supported from an optical quality coated window and a 28 mm focal length compound, achromatic eyepiece complete the optical system. Everything is pre-collimated requiring no user adjustments and the system is protected from dust and moisture by the window. The 2001 gives you a 17½ inch objective focal length with an effective magnification power of 16X. *There is no other telescope like it!*

Easy to Use

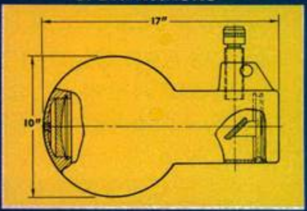
A uniquely designed, cast aluminum mount enables you to aim and use the 2001 with a simple fingertip control. Plus a selection of available accessories make the Astroscan 2001 the most versatile instrument you've ever used. Its phenomenal light-gathering power

lets you see stars as faint as the 12th magnitude under good viewing conditions opening new astronomical vistas you've only hoped for until now.

It's Tomorrow's Telescope You Can Own Now

The Edmund Astroscan 2001 is now in full production and available for immediate shipment. You can order yours today with the coupon below. Send check or money order or use your Master Charge, BankAmericard or American Express if you like.

SPECIFICATIONS



Telescope Type: Newtonian Rich Field Telescope (RFT). **Clear Aperture:** 4" (102mm) diameter; f/4.4. **Primary Mirror:** Pyrex® base, 4¼" (108mm) dia. 17½" (445mm) F.L. parabolic ⅛ wave. **Primary Mount:** Fixed, factory collimated. **Secondary Mirror & Mount:** Pre-aligned ⅛ wave diagonal 1½" minor axis (38mm) mounted to coated optical window. **Eyepiece:** 1¼" O.D., 28mm F.L. compound Achromatic. **Power:** 16X with above eyepiece. Other eyepieces or optional Barlow lens may be used to increase power. **Field of View:** 3.0° with eyepiece supplied. **Focusing:** Smooth, posi-grip, rubber roller focusing (25 feet to infinity). **Telescope Body:** Special, high-impact plastic. **Dimensions:** Length: 17" (432mm); Sphere dia.: 10" (254mm). **Weight:** 8.4 lbs. (3.8kg) without stand. Stand weight 2 lbs. (0.9kg).

SEND FOR FREE CATALOG

EDMUND SCIENTIFIC CO.
Dept. K01, EDSCORP Building
Barrington, N.J. 08007

Name____________________
Address____________________
City____________________
State__________ Zip__________

EDMUND SCIENTIFIC CO.

Dept. K02, EDSCORP Building, Barrington, N.J. 08007

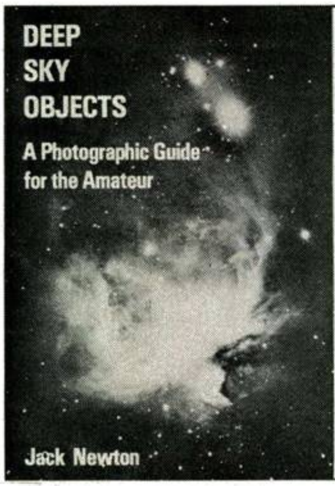
☐ YES, please send me ____ Astroscan 2001 Telescope(s) priced at $149.95 each plus $1.00 service and handling charge.
Enclosed is my ☐ Check ☐ M.O. for total of $____________________
Please charge my ☐ Am. Exp. ☐ BAC ☐ MC
Card #____________________ Interbank #____________________
Expir. Date____________________ Sig.____________________
Name____________________
Address____________________
City____________________ State__________ Zip__________

30-Day Money-Back Guarantee. You must be completely satisfied or return the Astroscan in 30 days for full refund.

ONLY
$\$149^{95}$

ASTRO-MART

Astro-Mart is a free, reader service department available only to current, paid, noncommercial subscribers; 2 ads are allowed per year. Each ad submitted must not exceed 40 words in length (including name, address, etc.). All ads are subject to editorial review for suitability. Be sure to allow 3-4 months for your ad to appear.



DEEP SKY OBJECTS
A Photographic Guide for the Amateur

This guide will help you to locate and identify more than 125 galaxies, nebulae and star clusters, including the complete Messier catalog.

The 75 full-page photographs are all taken with a 12.5 inch telescope to the same one-degree scale. Easily compare the size, shape and brightness of each object illustrated.

Over 50 two-color detailed finder charts quickly indicate when and where you can see these fabulous sights.
Send $9.50 ($12.50 deluxe) to
GALL Publications
1293 Gerrard St., E., Toronto, Canada

CELESTRON TELESCOPES
ON DISPLAY AND IN STOCK
E & W OPTICAL, INC.
2420 EAST HENNEPIN AVE.
DEPT. AM
MINNEAPOLIS, MINN. 55413
612-331-1187
SEND FOR PRICE LIST "A"—
Astronomy supplies and accessories

ASTRO-FILMS
35mm, 36-exp. rolls
•Kodak Spectroscopic with antihalation rem-jet backing
Choose 103aF, 103aE, or 103aO $6.19 ea.
3 or more $5.39 ea. 5 or more $4.59 ea.
•SO-410 (planets, moon, sun) $2.10 ea.
•High Contrast Copy (planets, moon, sun) $2.10 ea.
•2475 ASA 1000-4000 $2.65 ea.
Film information 35¢, free with order.
ASTROFILM
P.O. Box 2731, Dept. AM Akron, OH 44301

POTTER SALES & SERVICE
Celestron, UNITRON, STAR INSTRUMENTS,
VERNONscope, **UNIVERSITY OPTICS**,
DayStar Filters, DOAA, ASTROPHYSICS,
CROSS OPTICS

Demonstrations by appointment

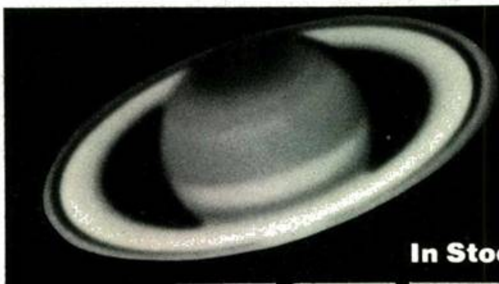
723 CEDAR, DEPT. AM,
SANDWICH, IL 60548
815-786-8168

FOR YOUR ASTRONOMICAL NEEDS

ASTROPHOTOGRAPHY
• RECORD BOOK •
ASTROLOG
666 DEAD CAT ALLEY WOODLAND CAL. 95695

Concise organized log for tabulating all pertinent astrophoto exposure data.
- Dew resistant pages
- Comb bound
- 360° swing open bindings
- Rigid covers for writing stability

$4.75 (incl. shipping)
Outside U.S. add $1.00 CA add 6% tax
ASTROLOG
666 Dead Cat Alley, Woodland, CA 95695



CELESTRON
5" and 8"
UNITRON
The Complete Line
TASCO
The Complete Line
GOTO
In Stock For Immediate Delivery

W A C K S
5722 W. North Ave.
Milwaukee, Wis. 414-442-3441
Midwest's Finest Selection Of Optical Equipment

25mm wide field Erfle eyepiece

This newly designed eyepiece gives increased field over 16 and 20mm Erfle eyepieces. Excellent color correction, resolution, and is hard coated on all surfaces. The ideal eyepiece for F4 and F5 rich field telescopes be it reflector or refractor. **$49.50.**

Superior Optics
2984 Fair Ave.
Dept. AM
Columbus, Ohio 43209

FOR SALE — EICO BW 300 brainwave monitor. Alpha waves produce audible signal. Completely assembled. Includes earphone, electrodes, electrode paste, battery, instructions. Like new. Price: $35.00. Write Dr. Frank Schmalleger, 1107 Water St., Lumberton, NC 28358.

FOR SALE — Celestron 8, tripod, wedge, special coatings, Celestron 10x40 finder, special eyepiece turret, eyepieces, full aperture sun filter, drive corrector, more. Mint condition; $900.00. Ship collect (original trunk) anywhere in U.S. Contact James Sloane, 555 Pierce St., #1432, Albany, CA 94706. Phone (415) 525-2895.

FOR SALE — 8" Criterion Schmidt-Cassegrain; all accessories including counterweights and camera mount. Telescope less than 6 months old; mint condition. Price: $725.00, pick up only. Contact Joseph Impelluso, 24 Buckingham St., Manchester, CT 06040. Phone (203) 646-7290.

FOR SALE — 3..1" Meade refractor with equatorial mount, tripod, all standard accessories, electric clock drive. Like new; seldom used; new, $393.00. Price: $290.00 plus shipping. Contact Gary Jones, 722 Summit Dr., West Bend, WI 53095. Phone (414) 338-2915 after 5 p.m.

FOR SALE — 14-1/4" f/5 tube assembly. Coulter optics. Meade tube, specially coated for minimal internal reflectivity. 50mm finder, 2" focuser. Excellent condition. Best offer over $700.00. Brandon eyepieces, mount extra. Contact Tom Krauss, 145 W. 79th St., New York, NY 10024. Phone (212) 580-9100.

FOR SALE — Cave 8" f/4.5 RFT, rotating rings, no mount; $175.00. Assorted Celestron eyepieces; $10.00 each. TeleDrive corrector with AC power pack, declination motor, mounting hardware for C8; $75.00. 8mm Brandon ocular; $35.00. Write Steve Reed, P.O. Box 763, Redondo Beach, CA 90277.

FOR SALE — 4-1/4" Edmund reflector, equatorial mount. No clock drive. Excellent condition; seldom used. Price: $100.00. Write John A. Rinaldi, 58 Greenfield Ave., Waterbury, CT 06708.

FOR SALE — Back issues of ASTRONOMY (February 1975 through November 1977), and other astronomy magazines. Price for all: $65.00. For details, contact Sandy Teal, 4003 Dogwood St., Burton, SC 29902. Phone (803) 524-0873 after 5 p.m.

FOR SALE — RV-6 Dynascope with 3 eyepieces; performs beautifully. Like new, used only 3 times; still in shipping boxes. Moving, must sell. Price: $210.00. Contact Don McCasland Jr., Rt. #1, Seligman, MO 65745. Phone (415) 662-8907.

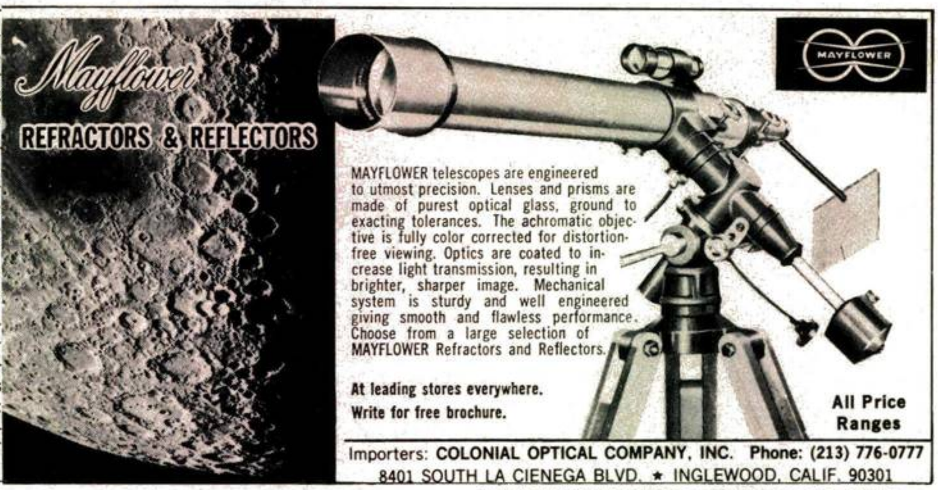
FOR SALE — Over 300 science fiction magazines (1929 through 1958). Also hardcover science fiction books. Priced for quick sale. For list, send SASE to Charles J. Merkle, 566 Lyonswood Dr., Hickley, OH 44233.

FOR SALE — Everything necessary for an 8" f/7 Newtonian (except tube). Coulter mirrors, 2.4" guidescope, drive, mount, custom made fittings. Valued at $450.00. Price: $250.00. Contact Bob Yoesle, 11400 Norwalk Blvd., Norwalk, CA 90650. Phone (213) 864-3186.

TRADE — Science fiction paperbacks, good condition only. No major repairs (i.e. missing covers or pages, stains). Will pay postage if you do same. Send list and SASE to Keith Welch, 489 Lawton Rd., Hilton, NY 14468.

WANTED — ASTRONOMY back issues: August 1973 through January 1976 inclusive. Complete set only; must be in good condition. State prices. Write Doug Currie, 153 Columbia Dr., Hamilton, Ontario, CANADA L9C 3Y7.

WANTED — ASTRONOMY back issues: September 1973 through February 1974; April through June, August, October, December 1974; January through April 1975; January 1976. Will pay any reasonable price and reimburse postage. Write Librarian, Royal Observatory, Blackford Hill, Edinburgh, EH9 3HJ, SCOTLAND.



MAYFLOWER telescopes are engineered to utmost precision. Lenses and prisms are made of purest optical glass, ground to exacting tolerances. The achromatic objective is fully color corrected for distortion-free viewing. Optics are coated to increase light transmission, resulting in brighter, sharper image. Mechanical system is sturdy and well engineered giving smooth and flawless performance. Choose from a large selection of MAYFLOWER Refractors and Reflectors.

At leading stores everywhere.
Write for free brochure.

All Price Ranges

Importers: **COLONIAL OPTICAL COMPANY, INC. Phone: (213) 776-0777**
8401 SOUTH LA CIENEGA BLVD. ★ INGLEWOOD, CALIF. 90301

CANADIANS

EDMUND SCIENTIFIC PRODUCTS

serves Canada's needs in ***TELESCOPES***

and all related accessories.

We are also authorized CANADIAN DEALERS for

CELESTRON

14", 8", 5", C90 on display

3500 BATHURST STREET
TORONTO, ONTARIO, M6A 2C6
(416) 787-4584

FREE EDMUND CATALOGUE and BROCHURE(S). PLEASE ASK

ANNOUNCING A NEW 6" F/5

NEWTONIAN TELESCOPE FOR $370

- *Crayford focusing mount
- *Tube rotates on rollers
- *Very rigid mount
- *Two eyepieces included
- *All pictured features are standard

For a free brochure of our telescopes and accessories, write to:

Jiri Bunata
Arcturus Telescopes
320 Fulton, #8 Dept. AM
Denton, Texas 76201

THIS QUARTER OF THE UNIVERSE IS OURS!

A HANDBOOK FOR BUILDING THREE DIMENSIONAL STAR MAPS: Computer coordinate translations of the entire **Near Star Catalogue** to 3D mode (X,Y,Z & Top View Polar). Several scales and sortings with helpful diagrams, special instructions for building a 3D map of the stars within 6 Parsecs, and general design advices. Data on nearly 2000 stars. **$6.00 ppd.**

HANDBOOK UPDATE DATA: Latest information from US Naval Observatory on some 300 additional stars and others recently researched and translated into 3D mode. **$3.00 ppd.**

THE ZETA RETICULI INCIDENT: Full color reprint of the famous **ASTRONOMY** series of articles. Highly controversial, over 10,000 copies sold. Did the Hills really see the starmap for some interstellar confederacy in a UFO? Read the data, build a starmap and decide for yourself. **$4.00 ppd.**

3D STARMAP KIT: 18" Space cube displaying 80+ nearby stars within 6 Parsecs, full data and key. **$24.95 ppd.**

ORDER FROM: Theta Enterprises,
829J Tejas Trail, Dept. AM Richardson, TX 75081

ASTRONOMY MATERIALS

ASTRONOMY
MATERIALS

Write today! Send six 13¢ stamps for MMI Astronomy Materials catalog plus supplements, includes hundreds of fine telescopic views in B/W and color on 35-mm slides and photos. **6 sets of 20 B/W slides /set** - $8.95/set ppd. General Astronomy, Galaxies, Nebulae, Sun, Solar System, Observatories.

Astro Posters: GIANT 23x29 in color. NEBULAE: N. Amer., Veil, Orion, Trifid, Rosette, Dumbbell, Serpens, Aquarius; Andromeda galaxy; Pleiades Cluster; PLANETS: Mars, Saturn. $2.95 ea ppd. Shipped rolled.

MMI CORPORATION
Dept. A, 3016 Cresmont Ave.
Baltimore, Md. 21211
(301) 366-1222

"Priceless . . ."

"Your Astronomy courses are excellent. Never have I undertaken any educational course where the school was more interested in actually wanting its students to LEARN what was taught, rather than issue a passing grade. What I have learned is priceless. Many thanks."

Jack D. Ellis, Oklahoma City, Oklahoma

Coast Navigation School specializes in individual instruction. Call or write today for our free course catalog describing our streamlined home study courses designed especially for amateur astronomers.

CELESTRON Schmidt-Cassegrain and UNITRON refractor telescopes available. Special prices on course/telescope combinations.

Coast Navigation School of Astronomy

Dept. 5358 418 E. Canon Perdido
Santa Barbara, CA 93102 / 805 963-7837

I'm interested! Please send me your free school catalog.

Name

Address

City

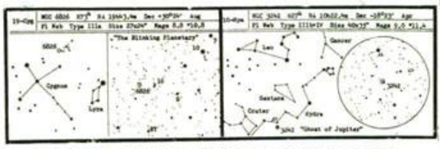
State, Zip

AMATEURS
in the
GULF COAST AREA

Celestron, Unitron, Meade,
Mayflower, Giesler "AccuTrack®"
DOAA, Vernonscope, Bushnell,
Swift, Fujinon, Zeiss,
and soon the new
"Quantum" Maksutov telescopes.

Texas Nautical Repair Co.

3209 Milam St., Houston, Texas 77006
Phone (713) 529-3551



INDEX CARD FINDER CHARTS

Made especially for use at the telescope!

SET I — THE MESSIER OBJECTS	$6.50
SET II — THE FINEST NGC OBJECTS	$6.50
SET III — THE FINEST DOUBLE STARS	$6.50

75. 3X5 CHARTS PER SET.

KODAK SPECTROSCOPIC FILM

35-mm., 36-ex. rolls with Rem-Jet backing.
Choice of **103a-E, 103a-F, 103a-O, $6.19** ea.
3 or more **$5.39** ea., 5 or more **$4.59** ea.
SO-115 $2.35 ea., 3 or more **$2.15** ea.

Astro Cards
P.O. Box 35, Natrona Heights, Pa. 15065

4¼" R.F.T. $99.50 ppd. USA

F/4.5 pyrex primary and 1.5" m.a. elliptical diagonal. Optics better than 1/8 wave. Aluminized and hard-coated. Precise course-fine helical focusing. 1¼" O.D., 27 mm Kellner for 18X; 3-degree field. Resin impregnated tube. Rigid factory collimination. Mounts on any photo tripod. No risk 30 day trial period. Illinois residents add 5% sales tax. Free catalog.

CHICAGO OPTICAL
Box 11309 Dept. A
227 E. Ontario Street
Chicago, IL 60611

NEWTONIAN NOTES

Designing and Building a High Performance Telescope from Commercial Components.

Topics include guides to selecting telescope type, f-ratio, and limits of performance. Extensive information on Rich Field telescopes. Guides are given to help select eyepieces, focusers, diagonal size, spiders, finders, etc. Drawings and text include construction of a high performance, 5" aperture Schmidt camera from commercial parts including optics for under $150. Special considerations for photographic use are covered. Telescope tube assembly instructions include how to lay out holes, making the large focuser hole, finding length of tube, and detail collimation instructions. Can be used to upgrade your present telescope.

NEWTONIAN NOTES by Peter Francis, 52 pages, 8-1/2 x 11, $4.45 ppd. Add 4% sales tax in Wis.

Kenneth Novak & Co.
Box 69B Ladysmith, WI 54848
Tel. 715-532-5102

WANTED — Science fiction magazines (1920 to 1975); any hardback science fiction books; aircraft, aerospace magazines. Also all types of comic books (1930 to 1977), especially those dealing with space, science fiction, astronomy. Write Ivan Herndon, 1832 Highland, Carrollton, TX 75006.

WANTED — August 1973 through January 1974 and April 1974 issues of ASTRONOMY. Will buy best offer. Preferably in New York metropolitan area (especially Long Island). Write Robert Hall, 72 Pine St., North Massapequa, NY 11758.

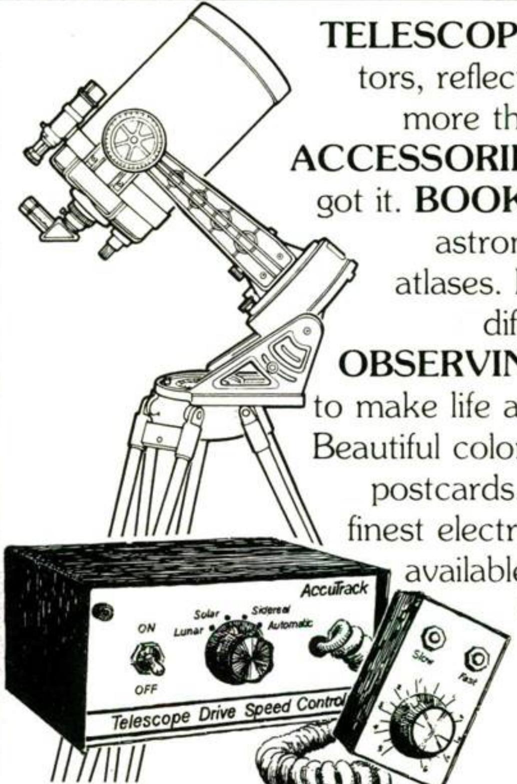
WANTED — Back issues of ASTRONOMY: August 1973 through December 1973; February 1974; February 1975. Write Jack R. Kettler, 23411 Meadow Lark, Oak Park, MI 48237.

WANTED — Progressive new astronomy group desperately needs persons interested in sharing both financial costs and scientific rewards of operating an observatory in central Indiana (Indianapolis area) with a 12-1/2" Newtonian. Call Ronald F. Nye, c/o Schneider Engineering Corp. Phone(317) 898-8282 days.

WANTED — New or used components, parts for construction of 12-1/2" reflector (tube, mirrors, mirror cell, equatorial mount, clock drive, etc.). Contact Gary Shore, 767 Caldwell Ave., North Woodmere, NY 11581. Phone (516) 791-8428.

WANTED — Plans for construction of Cassegrain (or Schmidt-Cassegrain) telescope; calculations for size and figure for secondary mirror (and aspheric corrector plate) vs. main mirror; mounting considerations; etc. Write Warren Spivack, 6625 Ave. M., Brooklyn, NY 11234.

WANTED — Back issues of "Celestron Techniques". State date, price, condition. Write Chris E. Spratt, 1468 Government St., Apt. 309, Penticton, British Columbia V2A 6T1, CANADA.



TELESCOPES: Celestrons, refractors, reflectors, spotting scopes— more than 16 different models. **ACCESSORIES:** You name it, we've got it. **BOOKS:** A huge selection of astronomical books and star atlases. **EYEPIECES:** Over 50 different oculars in stock. **OBSERVING AIDS:** Many items to make life a lot easier. **VISUALS:** Beautiful color slides, prints, posters, postcards. **ACCUTRACK:** The finest electronic telescope controls available. **EXPERT ADVICE:** Give us a call anytime. **LOW PRICES:** Need we say more? **FREE CATALOG.**

VISA master charge

ORION Telescope Center

A Division of
Gieseler Electronics

303 Potrero #6-C, Santa Cruz, CA 95060 (408) 425-1720

STAR INSTRUMENTS presents special savings for Christmas (prices effective through December 24, 1977)

NEW 28mm ERFLE has the widest *real* field of any 1-1/4" eyepiece we've tested. Computer ray traced to maximize corrections and to give sharp focus over entire *apparent* field (approx. 60°) and all surfaces are multi-coated. Coming soon — 8mm and 15mm Erfle. Unbelievably priced at $29.95 each ppd.

STARGAZER 6" f4 RFT tube assembly, $159.95 ppd. 1-1/4" focuser w/28mm Erfle (SAVE $10.00)

STARGAZER 6' f4 RFT tube assembly, $139.95 ppd. 1-1/4" focuser, no eyepiece

STARGAZER 6" f4 RFT tube assembly, $159.95 ppd. 2" focuser, no eyepiece

STAR Kellner Eyepieces 6, 12, 25, 40mm	$12.95 ppd.
STAR Orthoscopic Eyepieces 4, 5, 6, 9, 12.5, 25mm	15.95 ppd.
NEW 6" f10 Refractor -	
Basic Model	$799.95 TCC
(38x-480x) Deluxe Model	1199.95 TFC
NEW 4" f15 Refractor -	
Basic Model	$429.95 TCC
(38x-254x) Deluxe Model	749.95 TCC

Postpaid items shipped within Continental U.S.A. only. All other areas, transportation charges collect. (Calif. residents add 6% sales tax.)

For further details on our line of high-quality, lightweight and portable telescopes and telescope accessories, please send $1.00 ($2.00 in Canada and Overseas) for CATALOG 78a to:

STAR INSTRUMENTS
P.O. Box 1606, Dept. A
Costa Mesa, California 92626
Telephone: (714) 540-8729

WANTED — Projects, plans, schemes for equatorial mounting for 8", and clock drive and drive corrector for 220V./50 Hz. Write Luis Jose Herrero, San Modesto 14 4º D, Madrid 34, SPAIN.

WANTED — September 1973 through February 1974 issues of ASTRONOMY. Write Eric Huhndorf, 214-A Mountain St. E., Apt. 24, Worcester, MA 01606.

INFORMATION WANTED — On how to obtain color posters, photographs, slides, etc. from "Star Wars" and "2001: A Space Odyssey". Write Eric J. Borigini, 1130 Ambridge St., Anaheim, CA 92806.

INFORMATION WANTED — On location of California astronomy clubs, especially in Merced County. Also helpful hints on starting an astronomy club. Write Steve Maltos, 1249 Frank St., Dos Palos, CA 93620.

INFORMATION WANTED — On any Fortran or Basic programs used to compute planetary and cometary orbits. Please state price. Write Mike St. Clair, P.O. Box 97, Rosedale, IN 47874.

FREE — "The CONTACTER", a "noncontactee" oriented UFO newsletter. Issue No. 3: What airline pilots think of UFOs, new sightings, editorial comment. Send three 13¢ stamps for postage. Write PRO-UFO, c/o Donald F. Weitzel, 19740 Hart St., Winnetka, CA 91306.

ANNOUNCEMENT — Tampa Amateur Astronomical Society is involved in activities concerned with all areas of astronomy. For information, call Tom Campbell, president, at (813) 985-1842, or Eugene Osegovic, public relations chairman, at (813) 961-6980.

ANNOUNCEMENT — Our space program is in political trouble. Join the "Space Exploration Establishment" and reverse this trend. No dues; free monthly astronomy newspaper in color. Send SASE to Ken Croswell, S.E.E., 3775 Hambletonian Dr., Florissant, MO 63033.

You can not afford to buy a CELESTRON

WITHOUT CALLING US FOR THE MOST COMPETITIVE PRICES TO BE FOUND ANYWHERE.

SPECIALS THIS MONTH:

- CELESTRON 8 -

Special coatings, wedge, and tripod. (Save $370.) Sale price: $925.

- CELESTRON 90 -

Astro telescope with Celestron wedge and solar filter. (Save $250.) Sale price: $490.

Free shipping in Continental USA. California residents please add sales tax.

96 pages of catalogs and manuals: $2, refundable with first order.

Free price list on request.

Demonstrations by appointment, or call to discuss your specific needs.

OPTRON SYSTEMS

Eugene L. Cisneros
15840 East Alta Vista Way,
Dept. AM
San Jose, California 95127 U.S.A.
Phone: 408-259-4394

Celestron International

World's Leading Manufacturer of Quality Telescopes

2835 Columbia St. • Torrance, CA 90503 • U.S.A. • Telephone (213) 328-9560

AUTHORIZED INTERNATIONAL DISTRIBUTORS

Celestron has appointed the following companies exclusive distributors for the respective countries listed. Those of you interested in brochures or demonstrations of Celestron products should contact the distributors directly.

W. GERMANY, AUSTRIA, SPAIN, LUXEMBOURG
Treugesell-Verlag
4000 Dusseldorf 14
Schillerstrasse 17, West Germany

FRANCE
Societe J. & P. Medas
57 Avenue President-Doumer
B.P. 181-03206
Vichy, France

ITALY
Prodotti Gianni
20138 Milano
Via Mecenate, N-30/14, Italy

SWITZERLAND
Optik Foto Christener
Marktgass-Passage, 1
CH-3000
Berne, Switzerland

NETHERLANDS, BELGIUM
Polaris Wetenschappelijke Instrumenten
Bovenkerkerkade 62063, P.O. Box 33
Amstelveen, The Netherlands

SWEDEN, DENMARK, FINLAND, NORWAY
AB G Wendelholm
Box 14069 S-10440
Stockholm, Sweden

UNITED KINGDOM
Charles Frank Ltd.
144 Ingram St.
Glasgow — GI IEJ
United Kingdom

AUSTRALIA
Astro-Optical Supplies Pty., Ltd.
11a Clarke Street, Crows Nest
N.S.W. Australia

JAPAN
Koyo Corporation
Hibiya Park Bldg., Room 931
8-1 Yurakucho 1-Chome
Chiyoda-Ku
Tokyo, 100, Japan

REPUBLIC OF CHINA (TAIWAN)
Winson Trading Co.
5-1 Lane 145, Tun Hua N. Rd.
P.O. Box 54, Taipei, Taiwan
Republic of China

MEXICO
Fagsa
Calle 15 — No. 81
Mexico 18, D.F., Mexico

VENEZUELA
Foto Peter, C.A.
Centro Comercial Chacaito
Local 117
Caracus, Venezuela

SOUTH AFRICA
University of Witwatersrand
Planetarium — P.O. Box 31149
Braamfontein, 2017
South Africa

LIBYA
Mohammed Ben Barca Co.
P.O. Box 311
Tripoli, Libya L.A.R.

IRAN, IRAQ, QATAR, SAUDI ARABIA, UNITED ARAB EMIRATES
Baader Planetarium
Hartelstrasse 30
8000 Muenchen 21
West Germany

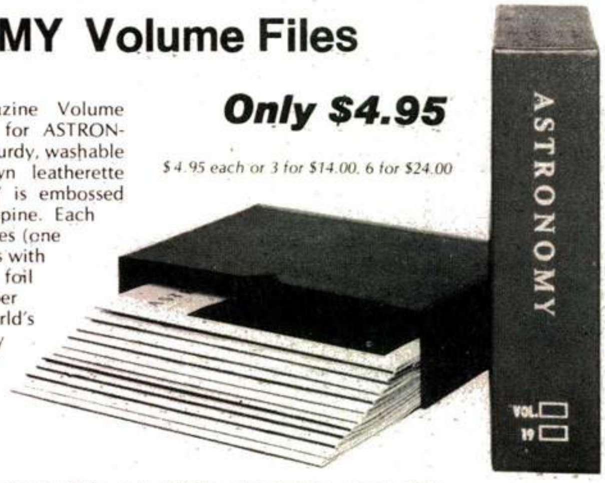
NEW DISTRIBUTOR INQUIRIES INVITED

ASTRONOMY Volume Files

Only $4.95

$4.95 each or 3 for $14.00, 6 for $24.00

Custom designed magazine Volume Files are now available for ASTRONOMY subscribers. These sturdy, washable cases have a rich brown leatherette finish, and ASTRONOMY is embossed in elegant gold on the spine. Each case holds 12 80-page issues (one complete year), and comes with a slip of gold signature foil to fill in volume number and year. Keep the World's Most Beautiful Astronomy Magazine beautiful year after year with this impressive addition to your library.



To order, simply fill in and mail the attached coupon today!

Use this address **ONLY** for Volume File orders and correspondence regarding them.

ASTRONOMY Volume Files
P.O. Box 5120
Philadelphia, PA 19141

Enclosed is $________ in payment for the following ASTRONOMY Volume Files:

________ 1 for $4.95 ________ 3 for $14.00 ________ 6 for $24.00

Name ______________________________

Address ______________________________

City ______________ **State** ________ **Zip** ________

U.S.A. orders only. Allow 3 weeks for delivery.
Full money back guarantee.

OPTICA b/c

ALL YOUR ASTRONOMICAL NEEDS FROM ONE SOURCE • OVER 10,000 ITEMS AND SERVICES

OPTICAL ACCESSORIES

BARLOW: 2x, multiple lens, coated, fully corrected for chromatic abberation, distortion free, sharp, brilliant.

24.5mm	**$14.95**
1-1/4"	**$18.50**

DIAGONALS: Star Diagonal-prism, eliminates awkward viewing positions. **Sun Diagonal** - eliminates 95% of sun's heat and light. Wedge type.

24.5mm	**$11.00 ea**
1-1/4"	**$17.88 ea**

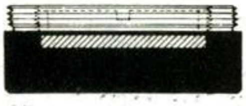
ERECTOR: Prism style, use telescope on land objects, gives proper left-right, up-down orientation.

24.5mm	**$24.05**
1-1/4"	**$29.58**

CLEANING SUPPLIES

Cleaning Fluid for Lenses	**$1.37**
Tissue, 4x6" packet	**.40**
Lens Brush	**1.71**
Optical Detergent for Mirrors	**1.37**
Special for first 3 items	**2.88**

ASTRO FILTERS



- **Penetrate Atmospheres**
- **Increase Contrast**
- **Intensify Color**
- **Eliminate Glare**
- **Professionals Use And Recommend Them**

Plane-parallel, solid Optical glass. Mounted in metal holders — screw into 1 1/4" eyepieces. Use light for aperatures less than 3", medium for 3" to 6". and dark for scopes over 6". Available in violet, blue, green, yellow, orange, or red.

Standard Series Special $4.95 each - 6 for $28.20

LATITUDE ADJUSTER FOR CELESTRON® 5 & 8"

Slips into wedge without tools, rigid, screw adjustment. Acquire precise polar altitude alignment with fingertip ease in minutes. **$29.95**

ASTRONOMICAL BINOCULARS

Richest Field, 25°, 155% more power and 250% more light than a 7 x 50. Use for comet hunting and meteor showers. See shimmering star clusters and lacy clouds of gas, etc. Includes lens caps, straps, carrying case and bracket to mount on tripod or Celestron piggy back mount. **11 power, 80mm objectives** Reg. $195 **Special $156.00**

35mm FILMS FOR ASTROPHOTOGRAPHY

Technical Pan (SO-115) Replaces SO-410 and SO-392, ASA 160, 36 exp. — For sun, moon, planets, etc. **$2.35**

High Speed Pan-ASA 4000, 36 exp. Extended red. Record more stars with shorter exposures **$2.60**

Spectroscopic Films 103a-E, 103a-F or 103a-O Finest films available for stars & nebulae. 125' roll, Regular $50.43 **Special,** per roll **$43.10** 5 rolls 36 exposure, any assortment. **Special $24.75** Shipped airmail, normally within 24 hours.

Tri-X Pan ASA 400, old favorite @ super-savings **20 exp. $.96, 36 exp. $1.33, $1.30, 100' bulk roll $8.03.**

Cassettes for loading film, **60¢ ea., 10 for $4.80.**

ASTROPHOTOGRAPHY CAMERA SYSTEM

Complete with 35mm SLR body, 1 sec — 1/1000 sec. focal plane shutter, telescope camera couplers, locking cable release for time exposures & instructions. Amazing value!

With Adapters for First Focus or Barlow Projection

	Eyepiece Size 24.5mm	**1 - 1/4"**
Regular	$145.90	$146.90
Special	**$ 86.34**	**$ 90.35**

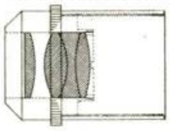
With Adapters for First Focus, Barlow & Eyepiece Projection

Regular	$163.46	$166.46
Special	**$104.90**	**$107.90**

SAVE 20% — 39th YEAR EYEPIECE SPECIAL

Choose from our highest quality precision oculars.

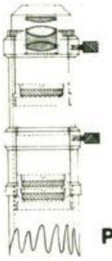
ORTHOSCOPIC



Focal Length	For 24.5mm Holders	For 1 1/4" Holders
4mm	$20.76	$22.00
5	19.96	22.00
6	18.36	22.00
7	18.36	19.96
9	18.36	19.96
12	18.36	22.00
18	19.16	22.00
25	20.76	23.60
32		38.80
40		55.60
WIDE ANGLE ERFLES		
20mm	27.16	30.80
25		41.20
32		65.20

ASTROFILTERS FOR OBSERVATION AND ASTROPHOTOGRAPHY

By Barbera, Capen, Carvalho and Steeg. Most complete edition, 102pp, 76 charts, photos, diagrams. Complete data curves on OPTICA b/c filters. Easy to understand. The how and why of filter use **$4.95**



VARIABLE DENSITY POLARIZING SYSTEM

Solves many observational problems: glare, color saturation, atmospheric penetration, moon light and more! Rotate your eyepiece and you have continuous variable density, light to dark. Combine with color filters and obtain just-right viewing intensity. Includes polarizing filters and adapter. Excellent for double stars.

For 24.5mm-Special $29.39
For 1-1/4" - Special $36.18

PHOTO COUPLERS SAVE 45%

Threaded for filters. Use eyepiece projection, first focus or Barlow.

	Reg.	Special
24.5mm	$34.90	**$19.20**
1-1/4"	$37.90	**$20.85**

Above prices cover most cameras. For the following **Add $10.80** — Alpha, "C" 16mm, Canonflex, Canon FX, TL, QL & Pellix, Contarex, Edixa Reflex, Leicaflex, Mamiya/Sekor, Olympus Pen F and OM-1, Praktina. **Add $23.50** — Icarex, Miranda Sensorex, Kodak Retina. **Add $49.95** — Hasselblad, Pentacon Six, Rolleiflex SL-66. **Add $59.95** — Bronica. Please specify camera make and model.

ACCESSORY CASE

Lightweight molded attache case. Foam pad interior, with cutout knife. Protect accessories from shock, dust, scratches. F.O.B. 5"x13"x18" **$29.88**

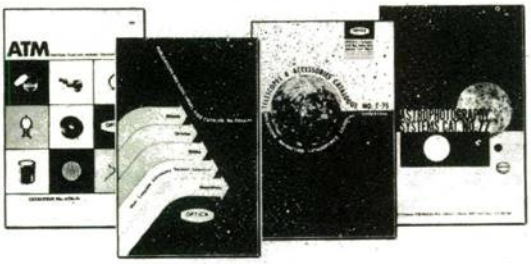
SPECTROSCOPE

See rainbow cut by Fraunhofer lines. Easily separates the D1/D2 lines of sodium. Reach 6th mag. with 4" to 6" scope. Adaptable for photography.

For 24.5mm - Special $71.64
For 1-1/4" - Special $73.39

SPECIALS EXPIRE END OF NEXT MONTH

4 OPTICA b/c Catalogues


ATM
TELESCOPES & ACCESSORIES CATALOGUE
ASTROPHOTOGRAPHY SYSTEMS CAT. NO. 77

(1) "Telescopes and Accessories" - over 250 items. (2) "Astrophotography" - systems, supplies, special films, chemicals, over 500 items. (3) "Publications & AVA" - over 300 books, atlases, maps, slides, posters, recordings, globes, etc. (4) ATM - goods for the telescope maker, over 400 items. Each catalog - 50¢; all four - $1.50 for handling and postage. Send cash, check or U.S. stamps. Also receive **FREE** current **Astronomical Events Calendar,** a wealth of useful information. **FOREIGN** — Each catalog $1.00; all four $3.00. Must be paid by an International Postal Money Order or a check drawn in U.S. dollars on any bank in the U.S.A. For Airmail, add $2.00

master charge

OPTICA b/c Company, U.S.A.. SALES/SERVICE DIVISION
4100 MacARTHUR BLVD., OAKLAND, CALIF. 94619, PHONE NO: (415) 530-1234

BANKAMERICARD

ASTRO-NEWS

Latest News From the World of Astronomy

Shuttle Payloads Signed For 1st Year of Operation

NASA has identified some 40 payloads for the 11 Space Shuttle flights scheduled for its first year of operation beginning in 1980.

Chester M. Lee, NASA's director of Space Transportation System Operations, said three civilian firms have deposited "earnest money" with the space agency covering payloads on eight flights. Additionally, NASA has firm plans for launching five payloads, and the Department of Defense, one.

"There are 12 non-NASA civil payloads, 10 NASA and 4 Department of Defense payloads forecast for launch during 1980 and 1981," Lee said. "Clearly the pipeline is beginning to fill up."

The Space Shuttle is the key element in NASA's Space Transportation System. It will make its first space test flight in 1979. Six of these orbital flight tests are scheduled, leading up to the first operational flight in 1980.

The Space Shuttle is a reusable vehicle which will be launched using a combination of solid propellant and liquid propellant rocket motors. After performing a mission of from 7 to 30 days in space, the Shuttle will return to Earth, gliding to a landing much as an airplane does. It will then be refurbished for additional flights in as little as two weeks.

Once operational, the Shuttle will replace the presently used expendable launch vehicles. Because of its reusability and capability of handling larger and heavier payloads, the Shuttle will reduce the cost of space operations, payload design and construction.

Allocation of payloads to specific flights is still in the early planning stage; final determinations will not be made until about one year before launch. Tentative allocations are:

Space Shuttle Flight 7 (flights 1 through 6 are test flights) — The Long Duration Exposure Facility (LDEF), a passive, free-flying satellite, will accommodate a large number of experiments to be conducted in space, and an experimental pallet.

Space Shuttle Flight 8 — Tracking and Data Relay (TDRSS-A) for Western Union and SBS-A, a communications satellite for Satellite Business Systems.

Space Shuttle Flight 9 — GOES-D, a geostationary operational environmental satellite for the National Oceanic and Atmospheric Administration (NOAA), and Telesat-E, a communications satellite for Canada.

Space Shuttle Flight 10 — TDRSS-B for Western Union, and SBS-B for Satellite Business Systems.

Space Shuttle Flight 11 — Spacelab 1, which is being built by the European Space Agency (ESA). This first Spacelab mission is a joint NASA/ESA science mission.

Space Shuttle Flight 12 — GOES-E for NOAA, and Intelsat 5 for Communications Satellite Corp.

Space Shuttle Flight 13 — TDRSS-C for Western Union, and Telesat-F for Canada.

Space Shuttle Flight 14 — Spacelab 2 for NASA.

Space Shuttle Flight 15 — Telesat-G for Canada, GOES-F for NOAA, and retrieval of the LDEF launched on mission 7.

Space Shuttle Flight 16 — TDRSS-D for Western Union, and SBS-C for Satellite Business Systems.

Space Shuttle Flight 17 — Spacelab 3, a multi-user mission with experiments in life sciences, technology and applications.

Other candidate Shuttle payloads to be flown on subsequent flights include NASA's Halley's Comet rendezvous solar-sail spacecraft, the Jupiter Orbiter Probe, and the Space Telescope.

An example of the savings possible by using the Shuttle for launching satellites is Flight 11. The Intelsat communications satellite presently is launched by the Atlas Centaur expendable launch vehicle.

The customer in this case is billed by NASA for the Atlas Centaur hardware, launch services and attendant costs totaling about $25 million. Similar launch services using the Shuttle will total about $21 million, and in the case of Flight 11, these costs will be shared by Comsat and Satellite Business Systems which will have its SBS-B satellite on the same flight. Charges to the two customers will be based on a formula that considers the weight and size of the two payloads and their destinations in orbit.

Cost savings for a Delta-class payload will be about $6.5 million per satellite when the Shuttle is used. NASA currently bills customers more than $15 million for a launch on its expendable Delta Rocket, while the bill for similar services on the Shuttle will be about $8.6 million.

Space Shuttle launches initially will be made from NASA's Kennedy Space Center, where existing facilities are being modified to accommodate the Shuttle.

By 1984, a second Shuttle launch/landing facility will be operated by the U.S. Air Force at Vandenberg Air Force Base, Calif. That site will be capable of handling Shuttle launches into polar orbits.

NASA has developed a working traffic model covering the 12 years beginning in 1980, and totaling 560 Shuttle flights. Peak activity will be reached in 1988 when 65 flights are anticipated — 46 from Kennedy and 19 from Vandenberg.

The first Orbiter (named Enterprise) is undergoing approach and landing tests at NASA's Dryden Flight Research Center, Edwards Air Force Base, Calif. The first orbital flight test is scheduled for launch from Kennedy in 1979, and the first operational flight is scheduled for 1980.

Lunar Stations Turned Off

On Oct. 1, 1977, science instruments left on the lunar surface by the Apollo astronauts were turned off, and the ALSEP (Apollo Lunar Scientific Experiment Package) Control Center at Johnson Space Center was dismantled.

The stations had completed their scientific objectives, and the data that could be obtained by continued operation was judged to be of lower priority than competing requirements for the financial resources, NASA spokesmen said.

Since July 20, 1969, scientists have been receiving a continuous stream of data from the five ALSEPs left on the lunar surface; much of what has been learned about the moon has been based on this information.

There were five operating stations — one each for Apollo's 12, 14, 15,16 and 17. The Apollo 11 crew placed a prototype station on the lunar surface in July 1969. That first station, with a design life of only 14 days, lasted 45 days and quit because of a power supply failure. The remaining five Apollo stations performed in an outstanding manner.

The total accumulated operating time for all ALSEP stations exceeds 29 years, although the equipment was designed for a cumulative total of only six years.

More than 153,000 commands were transmitted from Earth and executed by the moon stations. More than one trillion bits of lunar science and engineering data were received on Earth.

The stations were built to provide long-term lunar surface geophysical and electrical data. The surface experiments included measuring the heat produced by the moon's interior, the kind and amount of charged particles in the moon's tenuous ion atmosphere, the magnetic environment, and providing seismic data on moonquakes and meteoroid impacts.

Because of the extended life of the ALSEP stations, Earth scientists received two real bonuses: All four seismometers (one each on Apollos 12, 14, 15 and 16) had been operating as a seismic network for the past five years. This network greatly enhanced the analyses of the few large quakes which occur each year.

Secondly, a three-year accumulation of data from the heat flow experiment was required before scientists became aware of a long-term trend in the data. After much thought they realized it was caused by changes in the thermal properties of the soil created by the act of emplacing the probes. This understanding solved the argument between geochemists and geophysicists about the amount of radioactive material on the moon.

The seismic experiments especially intrigued scientists. From information based on moonquakes and meteorite hits, scientists felt they might finally be able to answer one of the moon's most perplexing questions: "What is the deep interior of the moon like, and does the moon have a molten core?"

To answer the questions, lunar scientists needed at least one large — greater than 10^{19} ergs (a unit of energy) — event on the back side of the moon, according to Dr. Gary Latham, principal investigator for the ALSEP passive seismic experiment. On May 13, 1972, a front side event with energy of 2,925 pounds (1,100 kilograms) was recorded. On Sep. 19, 1973, a large back side seismic event — with energy of 10^{18} ergs — occurred. Lunar scientists waited for a third event — "the big one" — but it didn't happen.

At the end of the fiscal year, the ALSEP stations were left on their own, all but their transmitters muted. Funding for the technical and scientific support needed to maintain the stations ceased on Sept. 30, 1977.

Knowledge and understanding about the moon increased tremendously over the past eight years. The returned lunar samples played an essential part in this knowledge explosion, but for some aspects, only the ALSEPS could have helped.

The ALSEP seismic information, magnetometer and heat flow experiments contributed the principal information about the moon's interior. It is now believed the moon's crust is multilayered and from 40 to 60 miles (60 to 100km) thick, with the secondary boundary occurring about 12 miles (20km) deep.

The upper mantle has been determined to be fairly homogeneous and to extend about 300 miles (500km). It's believed to consist of olivine or olivine-pyroxene matter, although other compositions have also been proposed. From 300 miles deeper, seismic data indicate the moon may be iron-enriched, although there is insufficient information to determine whether or not the moon has a molten core.

ALSEP *continued on page 67*

US, Germany to Participate On Jupiter Orbiter Mission

The Federal Republic of Germany has entered into an agreement with the United States to participate in NASA's Jupiter Orbiter Probe (JOP) mission, scheduled for early 1982.

A "memorandum of understanding" was signed in early October in Bonn, Germany, by Dr. Robert A. Frosch, NASA administrator, and by Hans Matthoefer, Germany's Federal Minister for Research and Technology (BMFT).

Scheduled to become the first planetary spacecraft to be carried aboard NASA's Space Shuttle, JOP is designed to conduct the most detailed scientific investigation yet of Jupiter, its environment and moons, including the first direct measurements of the planet's atmosphere.

The mission is composed of an orbiter which will circle the planet for at least 20 months, and a probe which will plunge deeply into Jupiter's atmosphere.

Under the agreement, BMFT will provide a Retro Propulsion Module designed for injection of the JOP spacecraft into orbit around Jupiter. It also will provide selected scientific instruments for integration into the payload, and the services of selected scientific investigators.

This cooperation with Germany advances the relationship established in the NASA/ BMFT cooperative probes (Project Helios) to the vicinity of the sun, carried out in 1975 and 1976.

The JOP team will consist of 114 scientific investigators, including 14 Germans. The orbiter will carry 10 instruments, and the probe will carry six. German scientists will be involved in the preparation and operation of both spacecraft and in the analysis of resulting data.

Jupiter, the largest planet, contains more matter than all the other planets combined, and holds many clues to the origin and evolution of our solar system. To understand the solar system, scientists need to understand Jupiter: to probe its atmosphere, map its magnetic field and radiation belts, and to examine the huge satellites that orbit it.

Although previous spacecraft have flown or will fly past Jupiter, JOP offers the first opportnity to make direct as well as remote measurements of the giant planet, its environment and satellites from various orbiting positions over a long period of time.

ALSEP *continued from page 66*

Moonquakes have been discovered to show periodicity and to recur at several places in the interior. The mechanism for this has been hypothesized as release of tidal stress in the region between 684 and 932 miles (1,100 and 1,500km) depth, and may occur along possible previously existing faults or local inhomogeneities at that depth. The time cycle of the deep-focus moonquakes follows the tidal cycles so closely that it appears likely the tidal forces are a major factor in triggering deep-focus moonquakes.

Charged particle, suprathermal ion and solar wind experiments also provided important data for a new understanding of Earth's magnetosphere and the interaction of the magnetosphere with the solar wind. Ion measurements also detected a lunar surface electric potential of about +10 volts in daylight and about -100 (periodically to -250) volts at night.

These experiments also supplied new information concerning the electrostatic lines of force associated with the transition of the terminator across the lunar surface. The phenomenon is thought to be the result of a cloud of hot solar wind electrons near the terminator (the cloud presumably generated by the limb shock of the solar wind).

Though the experiments have been terminated, the transmitters will continue to serve Earth as a reference point in astronomy. NASA's Jet Propulsion Laboratory will continue to use the signals from the ALSEP transmitters to assist in the laboratory's deep space work — including geodetic and astrometric studies and spacecraft navigation. Also, the motion of the lunar orbit will be accurately monitored against a background of extragalactic radio sources to test gravitational theories.

During the past eight years, many of the instruments associated with each ALSEP station experienced engineering problems. Since July, Johnson Space Center engineers performed more than their usual maintenance and engineering functions on the ALSEP stations. In preparation for the shutdown, the ALSEP stations were put through a slightly different routine to extract the last possible bits of engineering data.

There are a few engineering mysteries still puzzling the Johnson team, but each station over the years developed its own "personality"; a final understanding of those personalities will assist in the design of similar stations. The moon and Mars are the only planets now equipped with remote sensors, but it is expected that other planets will have them too, and a thorough understanding of the harsh environment involved and the effects of time will further enhance the reliability of these devices.

One station in particular, the Apollo 14 ALSEP, had a rather dramatic history of engineering problems. The ALSEP 14 station started working correctly and continued for four years; in March 1975, it quit for two days, and started up again! It quit again; then it started up again. This was repeated six times during its last two years.

The problem was diagnosed as an intermittent short circuit in one of two power conditioning units. The short was apparently related to the temperature of the unit, in turn related to the position of the sun over the lunar landscape. It is problems like this, however, that need to be fully understood to insure proper performance of future generations of remote science stations.

Over the years the ALSEP program cost approximately $200 million — including design and development of the stations themselves, support engineering work in Houston, and science analysis work performed in dozens of university labs throughout the world. The stations cost about $2 million a year to operate. The program involved hundreds of engineers and scientists, and produced a tremendous bank of information about the moon — both as a planet, and as an object wading through the electric and magnetic environment of Earth and the sun.

Arcturus Problem Solved

A worrying problem for theorists concerning the mass of the red giant Arcturus has been solved by observers. The result confirms that when looking at Arcturus, we are seeing a picture of our sun five billion years from now.

Observations made a few years ago indicated that Arcturus had much less mass than expected — under half that of the sun, which was too low for it to have reached the red giant stage in the history of our galaxy, according to accepted stellar evolution theories. According to one explanation, Arcturus must have shed mass. Alternatively, theories of stellar evolution were said to be wrong.

The problem has now been cleared up by Thomas R. Ayres of the Harvard-Smithsonian Center for Astrophysics, and Hollis R. Johnson of Indiana University; basic data about Arcturus is now known accurately.

To estimate the mass of a star such as Arcturus, you must first measure its surface gravity from characteristics of its spectrum. (Ayres and Johnson introduced a new and more accurate technique for doing this.) But an object's surface gravity will reveal its mass only if its diameter is known. So how big is Arcturus?

A red giant's diameter can be assessed by interferometer observations. In the case of Arcturus, which according to parallax measurements is 35-1/2 light-years away, the interferometer results yield a diameter 28 times that of our sun. Ayres and Johnson found a similar size, 27 suns, by an indirect approach based on the assumption of a surface temperature for the star of 7,200 degrees Fahrenheit (4,250 degrees Kelvin).

In a star of such diameter, Ayres' and Johnson's surface gravity measurements imply a mass 1.1 times that of the sun. This is satisfactory to the theorists, because more massive stars age quicker. Therefore, Ayres and Johnson confirmed that Arcturus was once a star similar to the sun, and has not lost any appreciable mass during its evolution to the red giant stage — in accordance with accepted theory.

Laser Output Increased

NASA scientists at Langley Research Center recently produced a nuclear pumped laser power output 100 times more powerful than that previously achieved with noble or inert gases. It reached 3.5 watts in a volume of only one cubic centimeter.

Experimental results demonstrated a major advance in nuclear powered laser technology — that is, converting the kinetic energy produced by splitting atoms directly into photons or light energy in the form of laser beams. This was accomplished without the energy wasting intermediate step of first converting heat to electricity.

In the experiment, neutrons caused fissioning or splitting of the helium-3 isotope into a proton and triton. In turn, these particles — in the presence of argon atoms — caused lasing or the production of the beam of energy (light).

The objective of this basic research is to develop a capability for efficient production and transmission of large quantities of power in space.

High powered laser beams could have a wide range of uses in space. They could connect central space power plants with settlements, materials processing centers and scientific operations in Earth orbit.

MANAGING EDITOR'S MEMO

On behalf of the ASTRONOMY staff, I'd like to express our deep gratitude to all of you who called or sent cards or letters to us upon learning of Stephen Walther's death. Your kindness and support have helped carry us through this difficult period.

* * * * * * * *

Since all of you had to flip past our new wrapper to get to this page, I won't beat around the bush. Our subject this month is a dirty, nine letter word: INFLATION!

Since August 1973, when the first issue of ASTRONOMY was published, we've provided you with the very best — and most beautiful — astronomy magazine possible. Since that first, skinny 48 page issue, we've increased the base number of pages in the magazine to 80 — that's 66 percent! We've increased the amount of color, and have continued to improve the editorial content and graphic appearance of the magazine. We've added several new departments to provide you with still broader coverage of the world of astronomy, and even published a special 112 page issue on the History of American Astronomy! And we managed to do all this without increasing subscription rates.

As we mentioned a few months ago, the time arrived for us to raise our subscription prices (to 1 year, $15.00; 2 years, $27.00) to offset the inflationary increases we've incurred over the past 4-1/2 years. And then, because we wanted to give you plenty of advance warning, we announced the new rates fully one year before their effective date (August 1978), and gave you an opportunity to subscribe or renew at our special Inflation Fighter rates — the lowest in ASTRONOMY's history!

Since July 1977, we've been hit with a 14.5 percent increase in our second class postal rates (the ones we pay when we mail ASTRONOMY to you each month). And the cost of the paper on which ASTRONOMY is printed has increased 20.7 percent — since September!

So, to make darn sure we can continue to provide you with the very best — and most beautiful — astronomy magazine possible, we have been working to eliminate needless expenses that don't affect the quality of the magazine itself. Beginning with this issue, we will mail ASTRONOMY to you with a protective overwrap (the extra paper cover that's stapled to your magazine), rather than in an envelope. The overwrap will not only protect the magazine on a more permanent basis and allow us to derive some savings — it'll also give us a chance to try out another money saving idea!

To date, we've always mailed your renewal notices to you first class. Now remember, the postage bite alone amounts to 13¢ times our total number of subscribers, times the number of renewal notices we sent you before your payment was received and processed!

Starting this month, as you approach renewal time, you'll receive your copy of ASTRONOMY in an overwrap that's been specially designed to incorporate your renewal invoice on the inside cover (thus affording us a savings in first class postage). Simply follow the instructions, making sure that your address label appears on the reverse side of your renewal invoice. You can return it to us (along with your payment) in one of the envelopes bound into the magazine.

That's all for now.

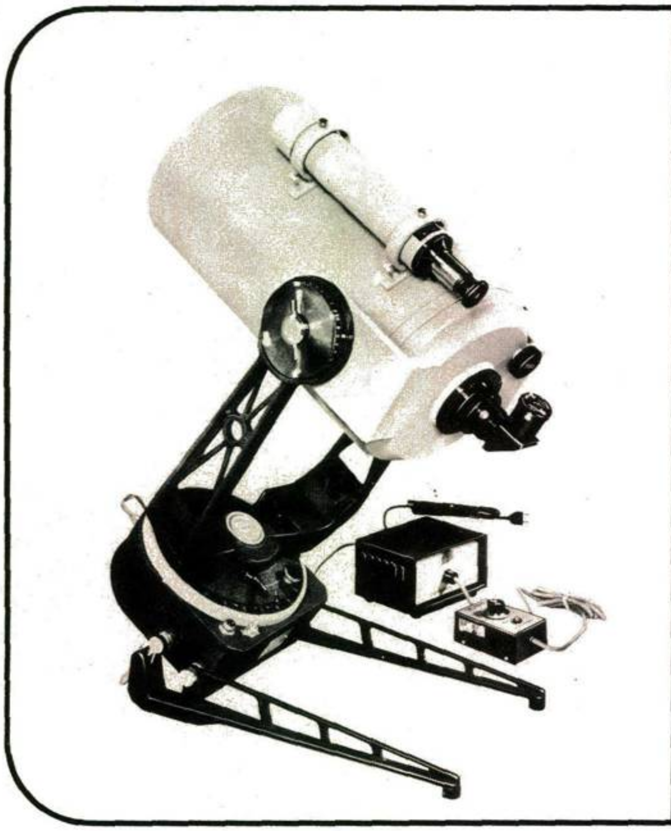
Happy New Year!

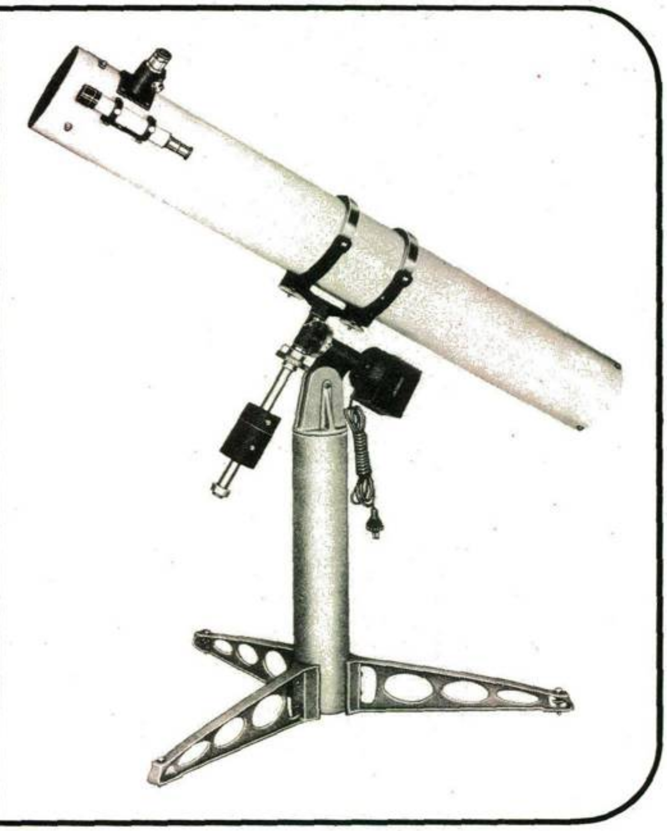
Penny Oldenburger

Penny Oldenburger
Managing Editor

Performance is the First Reason You're Proud to Own a Criterion

In telescopes, "excellence is as excellence does." Our Criterion instruments, with unsurpassed optics, rank among the world's most widely praised, because they perform brilliantly, reliably and with satin-smooth, effortless ease. The more demanding the conditions of use, the more you appreciate the ability of your Criterion to deliver exciting results. Whichever advanced design telescope you select, you get a superbly engineered instrument, guaranteed unconditionally. When you compare the pleasantly surprising prices you find further reason to choose Criterion. Please note that they are not "base" prices, but include everything described AT NO EXTRA COST. Only Criterion's leadership in efficient, modern precision production makes these prices possible.





Dynamax® 8 8-Inch Schmidt-Cassegrain

For Spectacular Results—Effortlessly.
Extra Features Without Extra Price.

This "never before" telescope created by Criterion gives you Schmidt-Cassegrain advantages at their best: full 8" aperture, wide field, with flawless resolution, yet weighs only 30 pounds for one-hand portability! It offers unprecedented versatility for viewing, superb telephotography, terrestrial uses, or technical applications. The exquisite optics, combined with super-precise electric drive plus variable drive corrector, combine to insure unsurpassed, unequalled ease of use because the extra features so necessary for superior results are designed-in and built-in... and INCLUDED in the price! ☐ AC, DC, and manual drives (variable, not just solar). You can easily dial in lunar, solar, sidereal, planetary etc. rates while observing for extra long monitoring. ☐ Large 8x50 finderscope has micrometer screw focusing ☐ Toggle switch with pilot light ☐ Engraved setting circles, observable from viewing position ☐ 3 eyepieces included ☐ Star diagonal, latitude adjusters, photo and telextender adaptors, and custom, fitted case. Ready for Total Performance with nothing else to buy!

As described, complete. FOB Hartford, Conn.
Shipping wt. 65 lbs. Express charges collect.

$875

Dynascope® RV-6 6-Inch Newtonian

For Exciting Viewing, Superb Value.
Price Includes Built-In,
Precision Electric Drive!

Professionals and astute amateurs and school or college users by the thousands know the breathtaking performance, this pace-setting telescope achieves. ☐ Exquisite optical system includes f8 parabolic aluminized mirror, guaranteed to reach all theoretical limits of resolution and definition ☐ Highly accurate Electric Drive uses regular AC, has smooth, self-acting clutch, permits manual operation ☐ Two 1¼" eyepieces, 70X and 140X, included. (others available) ☐ Highly stable equatorial mount with solid tripod, adjusts easily for any latitude ☐ Engraved setting circles for both right ascension and declination ☐ Tube rotates for adding cameras and comfortable viewing Easy, quick portability ☐ Smooth, brass rack-and-pinion focusing ☐ Handsome, white 50" Bakelite tube maintains perfect collimation ☐ 6x30 finderscope ☐ Fine workmanship throughout.

As described, complete.
FOB Hartford, Conn. Shipping wt. 77 lbs.
Express charges collect, $15 crating charge.

$249.95

Prompt shipment on both models. If you wish, phone us for delivery date.
To place your order, or request literature, write or call:

Criterion Manufacturing Company

Dept. CAS-61 620 Oakwood Ave., W. Hartford, Conn. 06110/Phone: (203) 247-1696
In New York, Robert T. Little, Eastern Sales Manager (212) 834-1888

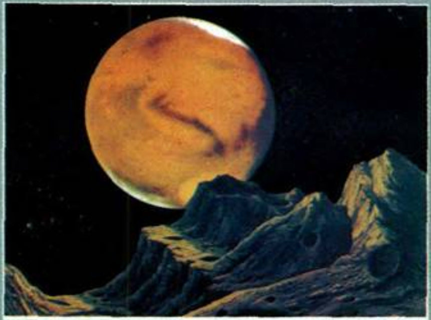
Inventory Clearance Sale!

Prices Reduced on Posters Calendars now ONLY $1.25 each

Milky Way in Sagittarius

Actual Poster Size: 17" x 22"

Better than a star atlas of this region, this breathtaking, colorful photograph by Orien A. Ernest shows clusters, nebulae and starclouds in their true relationship to each other and to the constellation Sagittarius' teapot asterism. In vivid reds, golds and blues, you'll see objects you can easily find with your naked eye or binoculars. Varnished; suitable for framing. $1.25 each.



Mars as Seen From Deimos

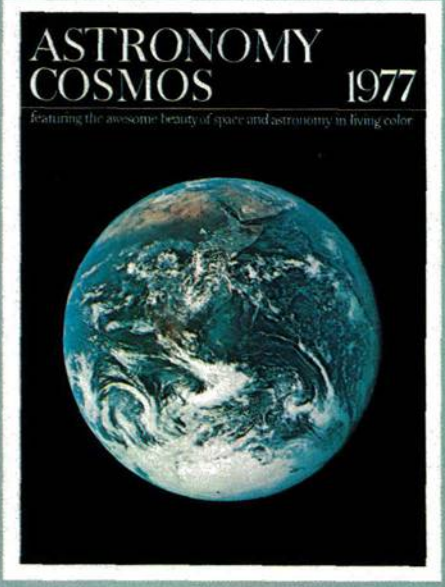
Actual Poster Size: 17" x 22"

Painted by Victor Costanzo, the red planet Mars and its outer satellite Deimos are set against a real stellar background. To the lower left of Mars is the Hyades, a star cluster in Taurus; at upper right is the constellation Aries. Varnished; suitable for framing. $1.25 each.

ASTRONOMY 1976 Sky Almanac

Opened Size: 11" x 17"

This full color calendar contains a series of 12 dynamic varnished reproductions of art and photographs from ASTRONOMY Magazine. As thrilling today as they were in 1976, you'll probably want to frame them! For an added bonus, ASTRONOMY 1976 Sky Almanac also contains maps of each month's sky — useful in any year — and introductory level observing projects. $1.25 each.


ASTRONOMY
COSMOS 1977
featuring the awesome beauty of space and astronomy in living color

ASTRONOMY Cosmos 1977

Actual Size: 8-3/4" x 11-3/4"

1977 may be "outdated", but astronomy . . . its drama *and beauty . . . is timeless.* ASTRONOMY's Cosmos 1977 calendar was designed to provide you with the most visually stunning view of the universe possible. Through 13 varnished, colorful reproductions of *cosmic art and photos, you'll travel the universe from* Mars to worlds beyond at the heart of a distant star cluster. Collect these illustrations . . . frame them (instructions are provided)! $1.25 each.

Start your own collection of cosmic art and photographs today! These impressive full color reproductions have been printed with the uncompromising care and quality found each month in ASTRONOMY, and will grace the walls of any room.

Quan.	Item	Price	Total
	Milky Way in Sagittarius	$1.25	
	Mars as Seen From Deimos	$1.25	
	ASTRONOMY 1976 Sky Almanac	$1.25	
	ASTRONOMY Cosmos 1977	$1.25	
	PLUS SHIPPING, HANDLING PER ORDER		$ .75
		TOTAL AMOUNT	

Payment must accompany your order.

Send check or money order to:
ASTRONOMY
411 E. Mason St. - 6th Floor
Milwaukee, WI 53202

Date:________________

Name________________________________
(please print)

Address________________________________

City __________ **State/Prov.** __________ **Zip** __________

Please allow 4 to 6 weeks for delivery.

The Cambridge Encyclopaedia of Astronomy

Recent discoveries have changed man's picture of the universe so greatly — and so rapidly — that many reference books are completely out-of-date. But there's a new book available — **The Cambridge Encyclopaedia of Astronomy** — that brings you a broad authoritative survey of every aspect of modern astronomy!

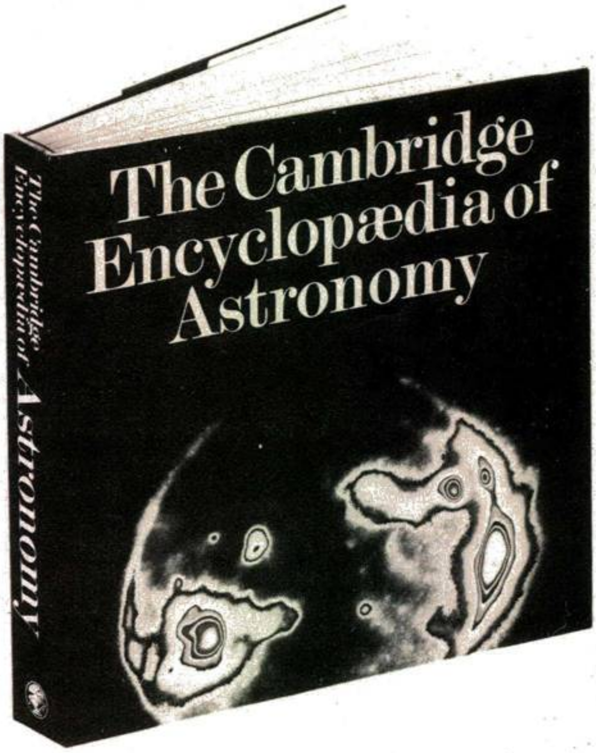
You'll find up-to-date astronomical information — a comprehensive survey of the solar system, a far-ranging discussion of stars and how they're born, change, and die, vast sweeping chapters on galaxies, and the very latest about the history of our universe.

The Cambridge Encyclopaedia of Astronomy has been written by a team of experts from one of the world's foremost centers for astronomical study — the Institute of Astronomy at Cambridge, England — and it's written to be read by a reader like you. You won't need a technical background to understand it — yet it's so completely authoritative that professional astronomers will certainly reach for it to refresh their memories.

Hundreds of beautiful illustrations — brilliant color photographs, charts, diagrams and historical pictures — complement the text and help make astronomy crystal clear. You'll find the Cambridge Encyclopaedia is a visual treat — and filled with new photos you've never seen before!

The Cambridge Encyclopaedia of Astronomy is completely indexed so you can find just about anything quickly and efficiently. The text is grouped into cohesive themes, and each section is written by a distinguished astronomer who is an expert on that subject! Difficult topics — black holes, neutron stars and other subjects at the frontiers of modern research — are introduced later as your astronomical awareness expands!

Whether you're a high school student, a nature lover, or just curious about astronomy — or you're seeking an ideal gift for a friend — **The Cambridge Encyclopaedia of Astronomy** is *the* astronomy book you've been looking for!


The Cambridge Encyclopædia of Astronomy
The Cambridge Encyclopædia of Astronomy

Actual Size:
9-3/4" x 10"
496 pages
150 color photographs
500 black and white photographs

Important Note:

Through special arrangements with the publisher, ASTRONOMY Magazine is offering **The Cambridge Encyclopaedia of Astronomy** for the special low price of $29.95 on orders received prior to December 31, 1977. After January 1, the price will be increased to $35.00.

Order *now* while our supply lasts!

Please send me ____________ copies of **The Cambridge Encyclopaedia of Astronomy** at ASTRONOMY's special low price of $29.95 each, plus $1.50 per copy for shipping and handling.

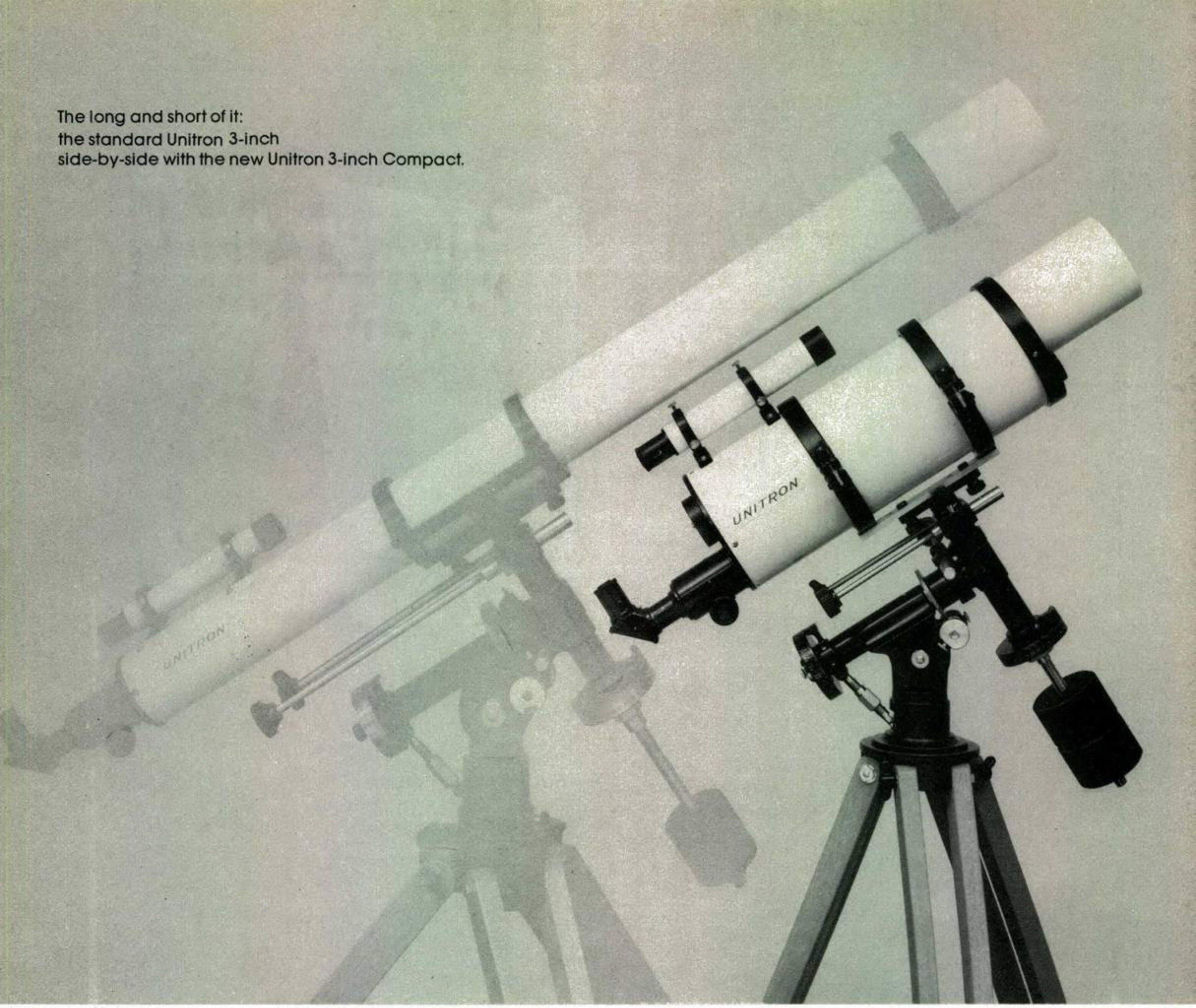
I am enclosing $31.45 for each copy ordered.
Please send check or money order to:
ASTRONOMY
411 E. Mason St., 6th Floor
Milwaukee, WI 53202 Date: ____________

Name ______________________________
(please print)

Address ______________________________

City ____________ State/Prov. ______ Zip ______

Please allow 4 to 6 weeks for delivery.



The long and short of it:
the standard Unitron 3-inch
side-by-side with the new Unitron 3-inch Compact.

Carry a handful of heaven.

Unitron folds a 4-foot lightpath into a 19-inch tube to give you a 3-inch refractor you can carry in one hand.

Now you can put the sun, the moon, the stars, the planets, the Crab Nebula and the Milky Way in a wooden carrying case only 9 inches square and 20 inches high. Unitron's new 3-inch Compact refractor telescope – the first of its kind commercially available – is housed in a tube only 19 inches long, five inches in diameter. It gives you the optical advantages of a refractor plus portability.

You get an achromatic, air-spaced, multicoated objective with a three-inch (75mm) aperture. It has a 1200mm focal length, f/16 focal ratio, 1.8 sec resolving power, 11.2 magnitude reach. Six coated eyepieces: 48x, 67x, 96x, 131x, 171x and 200x. The viewfinder is 8x, 30mm.

The sturdy tripod with famous Unitron equatorial mount has slow-motion controls on both axes, flexible cable control for right ascension, engraved setting circles, provision for motor drive. Precision rack-and-pinion focusing, erecting prism, star diagonal with achromatic amplifier, sun projection screen set, carrying case.

All this for less than $700!

The universe is yours in a magnificent small package from Unitron. Write today for full details on the amazing Unitron 3-inch Compact.

Now we want to hear from you.
Unitron Instruments, Inc.
subsidiary of Ehrenreich Photo-Optical Industries, Inc.
101 Crossways Park West,
Woodbury, N.Y. 11797, U.S.A.

UNITRON The value line

Please send me complete details
on your new Unitron 3-inch Compact. A–I

Name____________________

Address____________________

City____________________

State____________________Zip________

STAR DOME

JANUARY

by

James Mullaney and Henry J. Phillips

Our Close-Up region for this month is none other than Orion, the brightest and perhaps best known of all the constellations. Orion contains so many fascinating objects that we couldn't possibly squeeze an adequate description of them into our usual amount of space, so we therefore are presenting an extended Close-Up section this month. So much has been written about Orion that we could very well have decided to do an extended introductory portion of Star Dome instead and not run out of material! Instead, we'll mention a few of the lesser known stories about Orion before delving into the wonders of the constellation's deep sky objects.

We refer to Orion today as the "hunter", but actually it was only the Greeks and Romans who knew the constellation by this title. Most other nations appear to have thought of the group as a giant, including the Arabians, Hebrews, and medieval Germans. The latter called the group Orwandil, the name of a fearful giant in their legends.

Ancient Sumerians identified Orion with their god Ninurta — a war god who defended the other deities from their enemies. Once, when all of nature rose up against Ninurta, he fought off the attack with the help of only a few stones that remained faithful to him. After his victory, he blessed these stones by transforming them into precious jewels.

The natives of New South Wales in Australia told a somewhat lascivious story involving the stars of Orion's belt. Once a man surprised his wife bathing with another man; to escape his wrath, she fled into the sky where she became a star. The husband followed, carrying one of their children under each arm; the three became Orion's belt. The wife, however, would not return to her husband, and has spent eternity trying to find a way for her lover to join her.

The modern British writer J.R.R. Tolkien, in his epic fantasy **The Lord of the Rings**, refers at one point to "Menelvagor with his shining belt" and "blue Hollin" — the Elvish names for Orion and nearby Sirius. This is one proof that Tolkien's "Middle-Earth" (the site of his story) is actually supposed to be our own Earth in earlier days.

It's only natural that a star grouping of Orion's brightness and prominence should inspire innumerable legends, and many more are scattered throughout the world's mythology and literature.

Close-Up

Orion Region

Flammarion called it "the California of the Skies"; Barns, "the imperial constellation of the firmament"; Webb, "the finest"; Olcott, "the most brilliant", and Muirden "the grandest" constellation of the heavens. All these inspired exaltations can only refer to majestic Orion, the mighty hunter of the sky!

Barns left us with the most eloquent introduction to this month's region: "For those who would acquire a knowledge of the heavens in little, let him give up his days and nights to the marvels of Orion. Here may be found every conceivable variation of celestial phenomena: stars, giants and dwarfs; variables, doubles, triples, multiples; binaries visual and spectroscopic; clusters wide and condensed; mysterious rayless rifts and nebulae in boundless variety, with the supreme wonder of all supernal wonders at its heart — the Great Nebula — before which the learned and the laymen alike have stood silent in awe and reverence since the first lens unfolded to man's gaze its true vastness and intricacy.... To know Orion is to know astronomy!"

No other heavenly precinct contains so many bright, colorful stars in such a distinctive pattern as does Orion. As Olcott pointed out, its aspect even to the unaided eye on the dark transparent winter nights "delights the eyes of all beholders". It is also unequaled in its profusion of spectacular deep sky wonders. Clusters and nebulae abound here, and Webb cites nearly 100 double and multiple stars within its confines. Our table of selected objects only hints at the vast telescopic treasure awaiting stargazers.

Betelgeuse [Alpha (α) Orionis]

Let's begin our telescopic exploration of Orion by inspecting its two brightest luminaries — ruddy Betelgeuse and blue-white Rigel. The former is located at the northeast corner of the vertical parallelogram marking the hunter's body, while the latter occupies the southwest one.

Betelgeuse is a cool red supergiant sun of spectral class M2. Its vast globe pulsates in a semiregular manner that causes the star to vary in brightness from about 0.4 to 1.3 magnitude, over a period of roughly 2,070 days (5.7 years). Its variability was discovered by Sir John Herschel, who found that it was alternately brighter than Rigel and fainter than Aldebaran in nearby Taurus; most of the time it lies between the two in brightness.

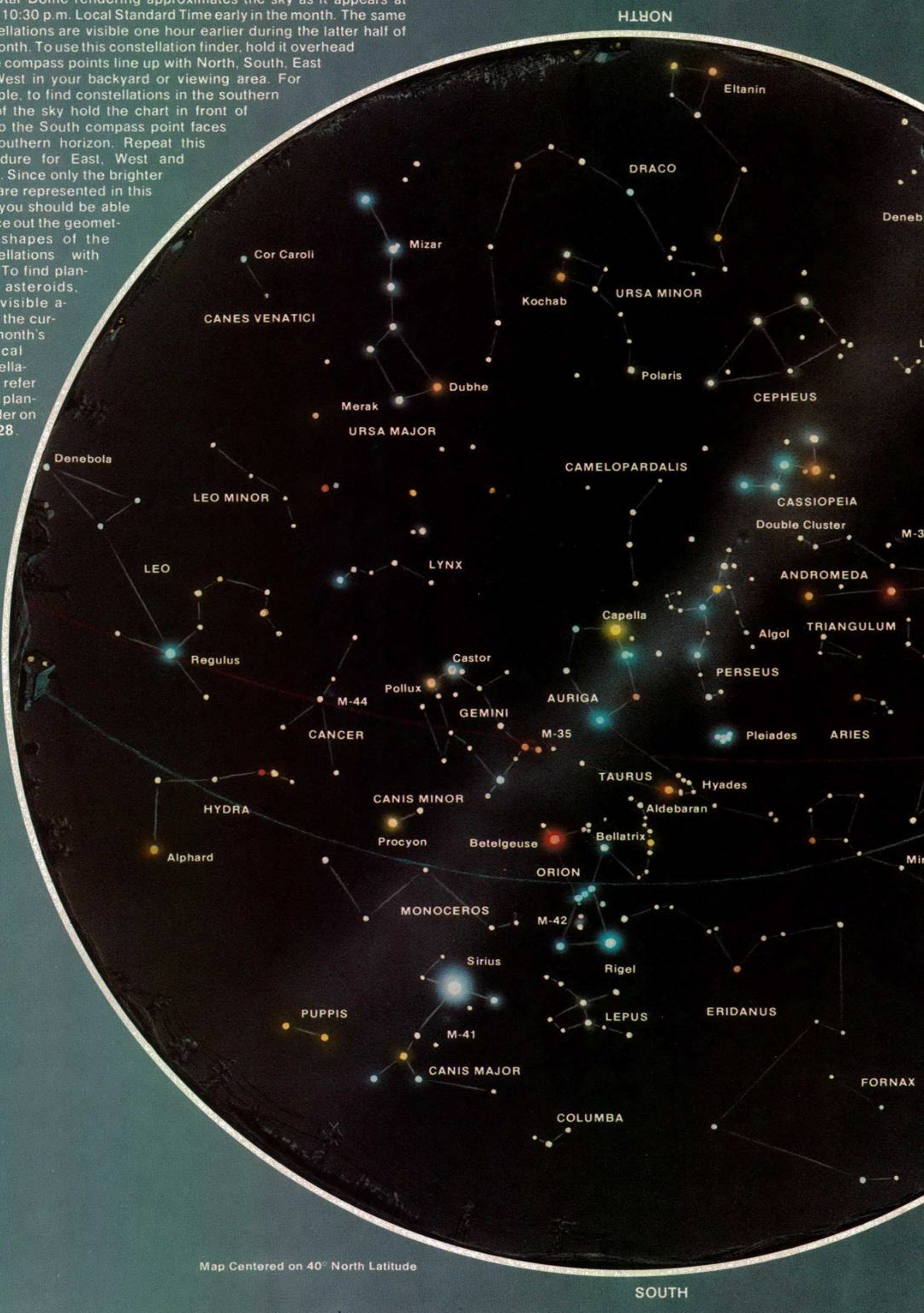
Betelgeuse is among the reddest of all bright stars, exceeded perhaps only by Antares in Scorpius. As Webb suggested to his readers long ago, look alternately at Betelgeuse and Rigel to appreciate the superb color contrast. Lassell described its appearance in his large metal mirrored reflectors as "A most beautiful and brilliant gem! Singularly beautiful in color, a rich topaz; in hue and brilliancy different from any other star I have seen." Its emberlike glow warms the observer on frigid winter evenings from across some 520 light-years of space.

Rigel [Beta (β) Orionis]

Orion's other outstanding cosmic jewel is Rigel. Like Betelgeuse, Rigel is also a supergiant sun, but a much hotter blue-white one of spectral type B8. Although more than a match in brightness most of the time, Rigel lies almost twice as far away (900 light-years) as Betelgeuse and therefore is intrinsically much more luminous.

Rigel is a double star that offers a

This Star Dome rendering approximates the sky as it appears at about 10:30 p.m. Local Standard Time early in the month. The same constellations are visible one hour earlier during the latter half of the month. To use this constellation finder, hold it overhead so the compass points line up with North, South, East and West in your backyard or viewing area. For example, to find constellations in the southern part of the sky hold the chart in front of you so the South compass point faces the southern horizon. Repeat this procedure for East, West and North. Since only the brighter stars are represented in this map, you should be able to trace out the geometrical shapes of the constellations with ease. To find planets, asteroids, etc., visible among the current month's zodiacal constellations, refer to the planet finder on page **28**.


NORTH
Eltanin
DRACO
Deneb
Mizar
Cor Caroli
Kochab
URSA MINOR
CANES VENATICI
Polaris
CEPHEUS
Dubhe
Merak
URSA MAJOR
Denebola
CAMELOPARDALIS
LEO MINOR
CASSIOPEIA
Double Cluster
M-3
LYNX
LEO
ANDROMEDA
Capella
Algol
TRIANGULUM
EAST
Regulus
Castor
PERSEUS
Pollux
M-44
AURIGA
GEMINI
CANCER
M-35
Pleiades
ARIES
TAURUS
Hyades
HYDRA
CANIS MINOR
Aldebaran
Procyon
Betelgeuse
Bellatrix
Alphard
ORION
Mi
MONOCEROS
M-42
Sirius
Rigel
LEPUS
ERIDANUS
PUPPIS
M-41
CANIS MAJOR
FORNAX
COLUMBA
SOUTH

Map Centered on 40° North Latitude

splendid contrast in brightness between its components. The primary shines at 0.3 magnitude and the companion at seventh. The gap separating the stars is nearly 10 seconds of arc, but it appears less because of the great brilliancy of the primary. Both suns seem fixed in their relative positions, but possibly form a long-period binary system.

Some observers consider the pair a test for a two inch telescope, while others claim at least four inches is needed for a clean split. The companion has been glimpsed with just 1-1/4 inches of aperture and forms more of an atmospheric than optical test. Even a 2.4 inch refractor at about 100 power will resolve Rigel when seeing (image steadiness) is good. The magnitude contrast becomes more striking as telescope size increases, and in large instruments this is one of the brightest and finest double stars in the sky. The view in a 10 inch reflector at 320 power is shown in our drawing.

Most viewers see the primary star a brilliant blue-white in cast and the companion white or blue. Smyth gave the colors as pale yellow and sapphire. Others have reported the small star as orange and even pale red! Webb called Rigel a "beautiful object" and stated, "I always see a blue tinge in the great star, resembling that of Vega."

Rigel also offers an enigma to observers, for the companion itself is suspected of being a very close and rapidly moving visual binary (both components are magnitude 7.7) whose separation never exceeds 0.2 seconds. Barnard and others reported it sometimes single and sometimes double through the great 36 inch refractor at Lick Observatory. We have seen it elongated in a 13 inch refractor at 290 power. How does it look in your telescope at high magnification on a steady night?

Zeta (ζ) Orionis

Our next offering is a triple star system that also happens to serve as a guide to one of the sky's most unusual and elusive objects. The star is Zeta Orionis, easternmost of the three matched gems that form Orion's belt; its proper name is Alnitak.

The trio consists of a second magnitude primary and a fourth magnitude companion a tight two seconds of arc apart, together with a 10th magnitude star 58 seconds distant. The close pair is considered a test for a two inch scope, but it's not easy even in a six inch most nights because of poor seeing conditions that prevail during much of winter.

Zeta appears in Pickering's roster under the heading of finest "White Double Stars", and all three components look blue-white to many observers. Some, however, have reported the brighter stars as yellow and reddish-olive, or yellow and blue. Smyth gave the colors as yellow and flushed blue, with the faint star gray. Webb pointed out that the brighter companion was "singularly missed by Herschel" and that it "seems of some nondescript hue, about which observers do not agree." Struve described this object's tint as "olivacea subrubicunda" (ruddy olive-green)!

Zeta is a convenient guide to the often photographed, but seldom seen, Horsehead nebula — a jet black cosmic cloud of obscuring matter in the shape of a silhouette of a horse's head. The Horsehead is part of an extensive region of nebulosity that includes Zeta itself; its brightest section is just east of the star and is designated NGC-2024. Found by Sir William Herschel, it is also known as H-V^{28} — number 28 in his class V (very large nebulae). This roughly circular cloud measures about 30 minutes (1/2 degree) in diameter and is best seen by placing Zeta just outside the edge of a medium power eyepiece field.

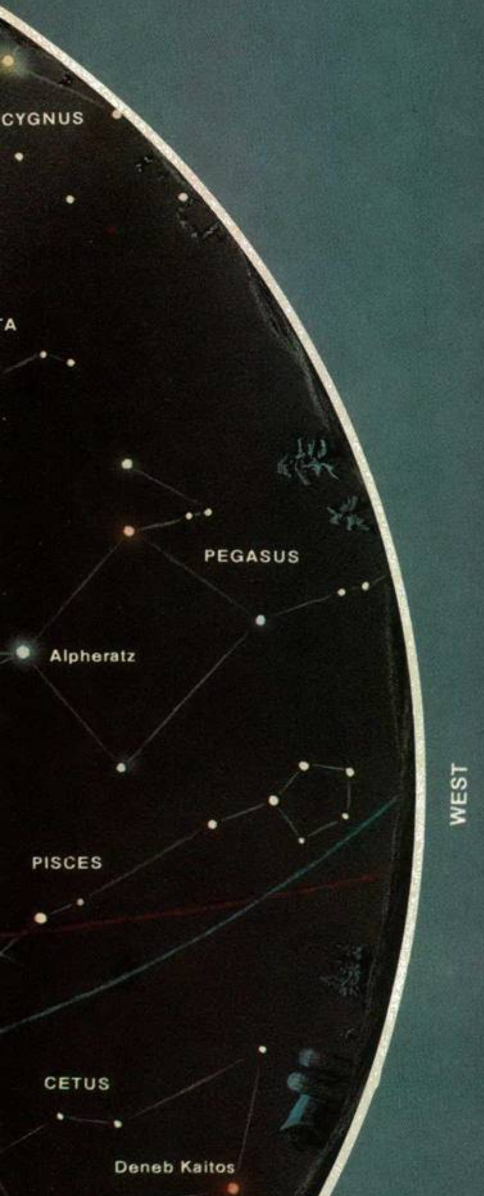
Should you succeed in catching a glimpse of NGC-2024, you are ready to try for the much more difficult Horsehead itself. Begin by slowly sweeping from Zeta to a point about one degree due south of the star. Using extreme averted vision on a very dark night, you may see IC-434 — a vertical shaft of ghostly luminescence measuring 60 by 10 minutes and extending southward from Zeta. A small dark indentation in this shaft of light marks the Horsehead, whose official designation is Barnard 33.

Detecting the Horsehead and its associated nebulosity seems to be more a matter of sky conditions and observing skill than of telescope size. The famed variable star observer and comet discoverer Leslie Peltier has glimpsed it with just 25 power on a short focus six inch refractor. It has even been suspected in large aperture binoculars from desert and mountaintop locations.

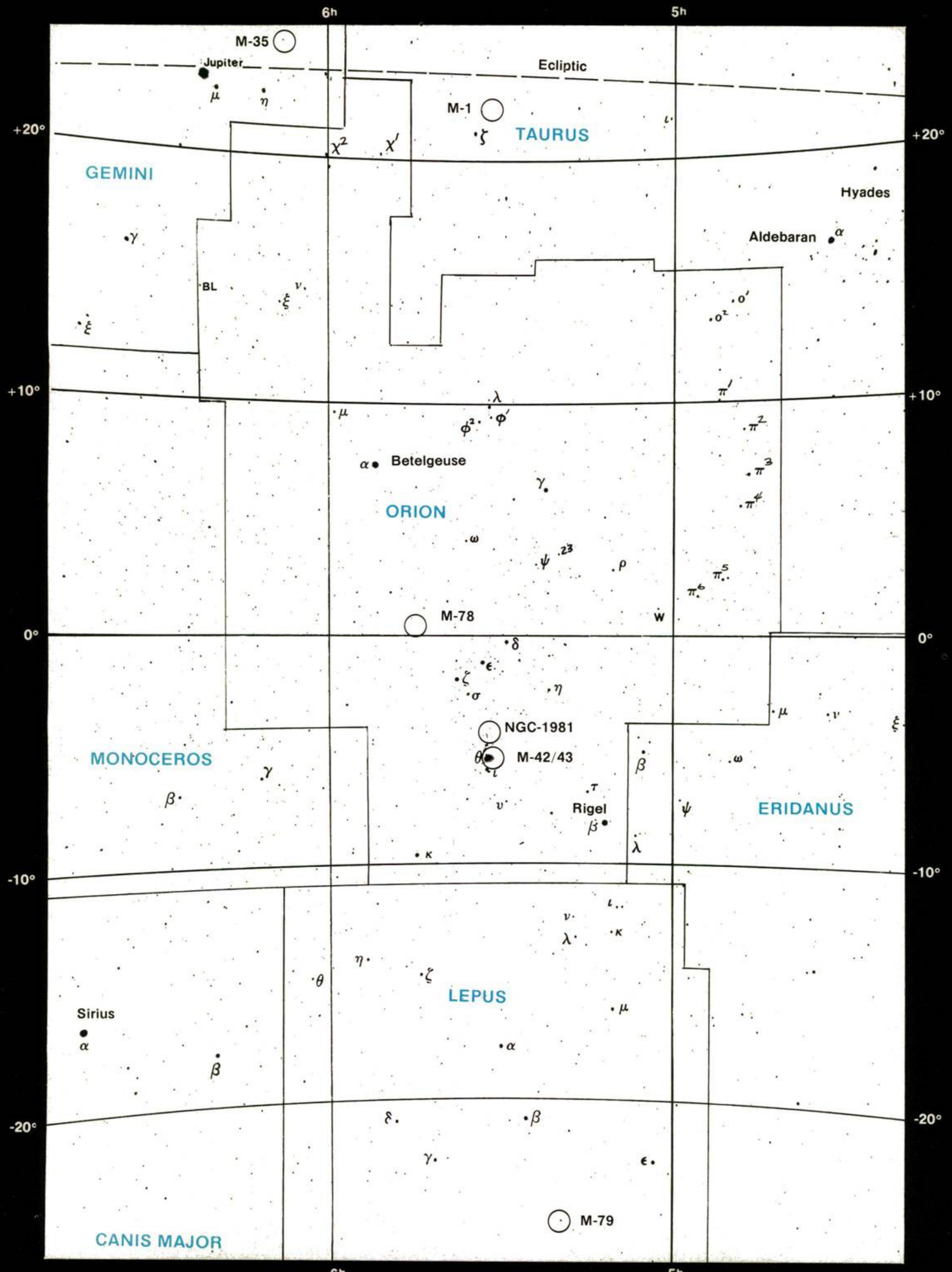
M-78

If you've been frustrated in your attempts to view the Horsehead nebula, you may find some compensation in our next target. This small diffuse nebulosity, known as M-78, can be found by sweeping with a low power eyepiece about 1/4 the way along a line from Zeta to Betelgeuse. You can also pick it up by setting your telescope on Delta (δ) Orionis (westernmost of the belt stars and a neat wide double) and sweeping due east to a point northeast of Zeta.

M-78 measures about eight by six minutes in angular size and shines near 10th magnitude visually. The nebula is illuminated by a pair of ninth magnitude stars separated by about 50 seconds of arc, the northern member of which is itself a two second



Map by Adolf Schaller


6h
5h
M-35
Jupiter
Ecliptic
M-1
TAURUS
+20°
GEMINI
Hyades
Aldebaran
BL
+10°
Betelgeuse
ORION
M-78
W
0°
NGC-1981
M-42/43
MONOCEROS
Rigel
ERIDANUS
-10°
LEPUS
Sirius
-20°
M-79
CANIS MAJOR

Photograph by Brad Wallis and Robert Provin/ Map by Henry J. Phillips

double with an 11th magnitude companion.

Messier authority Holyoke described M-78 as an "easy object in a three inch reflector but not particularly spectacular. An eight inch telescope brightens it some but otherwise adds little." Muirden called it a "faint concentration with a definite 'combed' structure".

Going back in time, Barns recorded this object as a "Weird gaseous nebula. North edge clean cut, south portion diffuse. Interesting!" Webb saw it as a "singular 'wispy' nebula" and added "best defined north". Our drawing shows the scene in a six inch reflector at 50 power, including the wide double.

Recent work by Russian astronomers suggests that the dark structures seen in M-78 are shadows cast by a preplanetary disk in the process of condensing. As you stare through the porthole of your telescopic spaceship at this gossamer patch in the sky, imagine it: a solar system in the making before your eyes!

Sigma (σ) Orionis

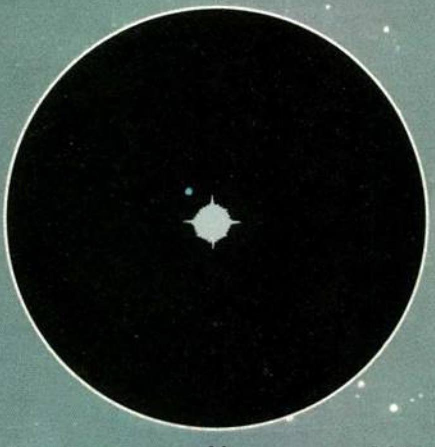
Heading southward now in preparation for our rendezvous with the Orion nebula, let's pause to check out a bright and colorful multiple star that's sure to delight you. This is Sigma Orionis, visible to the unaided eye just southwest of Zeta.

Here we find a stunning field composed of two distinct stellar groupings. One of these is Sigma itself — a system of *five* (3.9, 5.9, 7.2, 6.5 and 10th magnitude) suns at distances of 0.3, 13, 42 and 11 seconds, respectively. The bright close pair is unresolved in small telescopes and appears as a single star of fourth magnitude, while the remaining three can be seen in three and four inch instruments.

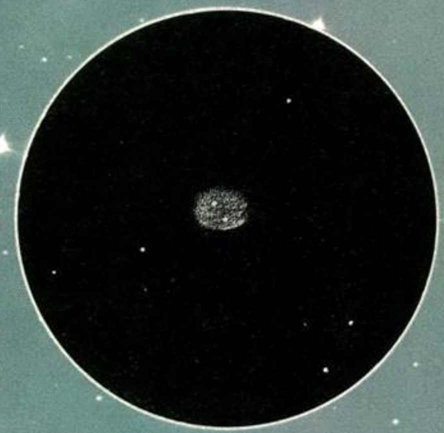
Adding to the beauty of this scene is the second group: a triple star known as Struve 761. This is an eighth to ninth magnitude trio of suns northwest of Sigma, with separations of 8 and 68 seconds. Webb described this object as a "beautiful little triangle" and gave the colors as all white. Both groups are shown in our drawing, as seen through an eight inch reflector at 90 power.

In order of brightness beginning with the blended primary, we see Sigma's tints as yellowish white, blue, reddish purple and white — but others have seen them differently. Webb noted the 7.2 magnitude star as ruddy

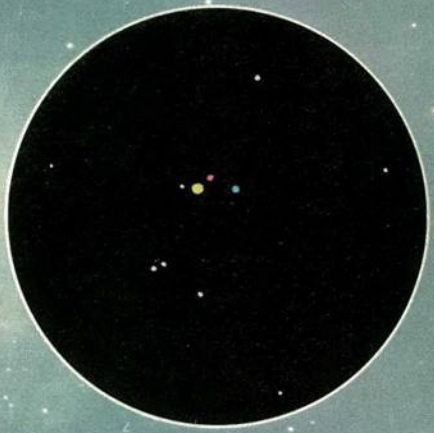
Top to bottom: Rigel, Orion's brightest star, is a fine double with a seventh magnitude companion. It is shown here as seen through a 10 inch reflector at 320 power, with a field of view of three minutes of arc. M-78 is a small diffuse nebula of about 10th magnitude, with two small stars near its center. Our drawing shows it as seen through a six inch reflector at 50 power; the field of view is one degree. Sigma Orionis is a beautiful, varicolored multiple star; also in the field is the triple Struve 761. We see it here through an eight inch reflector at 90 power; the field of view is 30 minutes of arc. Drawings by James Mullaney. The Orion nebula (M-42 and 43) is one of the finest deep sky objects, well viewed through all sizes of telescopes. This is a 30 minute exposure on Fuji R-100 film, made with an eight inch Celestron at f/5. Photograph by Stephen C. Reed.



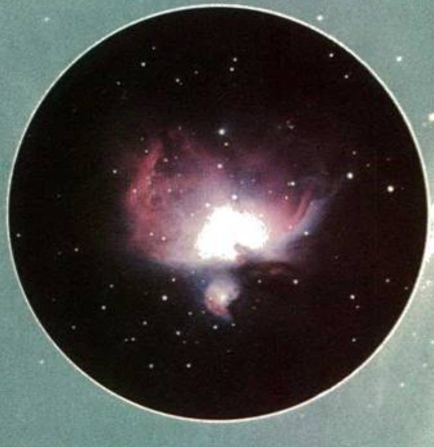
Rigel N 320x



M-78 N 50x



Sigma Orionis N 90x



M-42 and 43 N

Selected Objects — Orion Region

Object	Type	Mag.	Size/ Sep.	R.A. (1950)	Dec.
W Orionis	V:212^d	5.9-7.7	—	5^h03^m	+01°07'
* β (Beta)	★2	0.7,7.0	10"	5^h12^m	−08°15'
23 Orionis	★2	5.0,7.0	32"	5^h20^m	+03°30'
η (Eta)	★2	3.7,5.1	1.5"	5^h22^m	−02°26'
δ (Delta)	★2	2.5,6.9	53"	5^h29^m	−00°20'
λ (Lambda)	★2	3.7,5.6	4"	5^h32^m	+09°54'
* NGC-1981	OC	5	60"?	5^h33^m	−04°52'
* M-42/ 43	DN	4	66'x60'/ 20'x15'	5^h33^m	−05°25'
* θ^1 (Theta 1)	★4	6.8,7.9, 5.4,6.8	9",14" 22"	5^h33^m	−05°25'
ι (Iota)	★2	2.9,7.4	11"	5^h33^m	−05°56'
* σ (Sigma)	★5	3.9,5.9, 7.2,6.5,10	0.3",13" 42",11"	5^h36^m	−02°38'
* ζ (Zeta)	★3	2.0,4.2,10	2.4",58"	5^h38^m	−01°58'
* M-78	DN	10	8'x6'	5^h44^m	+00°02'
* α (Alpha)	V:5-6^y	0.4-1.3	—	5^h53^m	+07°24'
BL Orionis	V:?	6.3-6.9	—	6^h23^m	+14°45'

* Detailed in Close-Up

★2 = Double Star
★3,4,5 = Multiple Star
V:#^{y,d} = Variable Star, period
DN = Diffuse Nebula
OC = Open Cluster
Mag. = Magnitude
Sep. = Separation

at one time and blue another, while Smyth gave the colors of the three brightest members as bright white, bluish, and grape red (in that order). Bernhard, Bennett and Rice called Sigma "a very remarkable multiple star", and listed the hues as gray, blue, red and white. Still others find all three companions ashy in cast. What do you see?

Pickering included the Sigma system in his list as one of the finest multiple stars, with the comment "a sextuple star which appears as a double triple". It takes a little extra something to be a showpiece in the glamorous Orion region, but this object is certainly just that!

NGC-1981

Our final stop before arriving at the Orion nebula is another object on Pickering's list of the "finest". This is the coarse open cluster NGC-1981, just north of the great nebula itself near the stars 42 (sometimes called c) and 45 Orionis. Few star charts plot this object, and it is generally known as c Orionis, the designation Pickering gave it in his list.

The star itself is an unimpressive close binary of magnitudes 4.7 and 8.6, with 1.6 seconds separation. Together with 45 Orionis, it lies on the southern edge of a wide scattering of a dozen or so stars strung out in an east-west direction over nearly a degree. Included are two other pairs — Struve 750 (magnitudes six and eight, separation four seconds) and Struve 743 (magnitudes seven and eight, separation two seconds).

Webb called this a "brilliant field" and added: "A grand neighborhood; sweep well over the whole space, from 42 to Iota." The latter object is a pretty double with another pair in the field, on the opposite side of the Orion nebula from 42 and 45. All these stars are involved in faint nebulosity connected with the great nebula, which can be glimpsed in four to six inch telescopes on a dark night.

NGC-1981 is not very impressive as a cluster, and we might have bypassed it entirely if it weren't on Pickering's roster. He appears to have overrated this object; in his 11 inch refractor at 65 power with a field of view of 40 minutes, he considered this loose knit clan superior to the Pleiades! We can hardly agree with this assessment; what about you?

M-42, M-43, Theta 1 (θ^1) Orionis

We come at last to the real glory of Orion — Barns' "supreme wonder of all supernal wonders" — the magnificent Orion nebula. Volumes have been written about this object, and we could easily have devoted all of this month's Star Dome to it! What follows is of necessity only a sampling of observations and facts about this, perhaps the finest diffuse nebula in the heavens.

The nebula itself is visible to the unaided eye as a greenish haze surrounding the Theta stars in Orion's sword, and its grandeur is apparent even in binoculars. Strangely, it was missed by Galileo, who paid considerable attention to this part of the sky with his new "optik tube".

The Orion nebula is a stellar incubator within whose enormous confines new stars are being formed. It is said to contain enough matter to make a star cluster and is, in fact, doing just that as evidenced by the Trapezium (see below) and its surrounding hot, newborn stars. It is the radiation of these very stars that cause the nebulosity to glow by fluorescence so that we can see it.

Most color photographs show this vast cloud as pink or reddish in hue, in contrast to the eerie green glow seen by the eye. Film emulsions usually used for photos are sensitive to different wavelengths of the nebula's light than the eye. It's both fun and instructive to compare observatory photos with what can be seen at the eyepiece of your own telescope. Unfortunately, these usually overexpose the heart of the nebula, "burning out" the varied and fascinating detail to be found there. Astrophotographers might like to try a graded series of exposures, aimed at recording just what the eye sees.

The Orion nebula consists of three distinct parts — the main nebulosity itself (M-42), its northeast wing (M-43) separated by a bridge of obscuring matter forming the dark "Fishmouth" intrusion, and the multiple star known as the "Trapezium" (Theta 1 Orionis) at its heart. Also present is Theta 2 Orionis, a wide double seen projected against M-42.

M-42 measures at least 66 by 60 minutes (over a degree!) in extent, including its faint loops and filaments. M-43 lies about seven minutes away and is a roughly circular patch 20 by 15 minutes in size, surrounding a ninth magnitude star. Many observers never notice M-43 — or at least don't recognize it as such — because of the overpowering presence of M-42 itself.

The Trapezium consists of four stars of magnitude 6.8, 7.9, 5.5 and 6.8 at separations ranging from 9 to 22 seconds. There are also two other closer members of about 11th magnitude, as well as several much fainter ones. Even a two inch telescope at 35 power shows the four primary suns, and a four inch at 45 power reveals the two secondary ones. All six have been glimpsed in good seeing with a three inch refractor.

This object ranks among the finest multiple stars in the sky for small instruments, and it appears on everyone's list, including Pickering's. Its members look white on first inspection, but definite traces of color contrasts can be seen — especially in six inch and larger apertures. Perhaps the best account of these is that given by Smyth, who saw them — in order of brightness — as pale white, faint lilac, garnet and reddish. With the greenish nebula as a backdrop, here is a sight sure to thrill star lovers!

Two of the bright Trapezium stars are eclipsing variables — one of which was only recently discovered to be so. Every 65 days it drops over 1/2 magnitude in a period of 10 hours or so, and then recovers full light in a similar interval.

The Orion nebula complex takes magnification well — indeed, any and all powers are useful here. To see the faint wispy outer extensions, use low power and sweep back and forth across the nebula for maximum contrast. Another technique is to place the nebula outside the eastern edge of a low power eyepiece field and allow it to drift slowly across your view. Of course, use of averted vision and a dark transparent night will help greatly here.

At 100 power or more with six inch and larger telescopes, the brighter portions of the nebula — especially near the Trapezium — show a complex mottled structure. The best description of this is that given by Sir John Herschel long ago: like "a curdling liquid, or a surface strewed over with flocks of wool, or the breaking up of a mackerel sky". The greater the aperture and magnification, the more dramatic this effect becomes.

Webb devoted several pages to a description of the Orion nebula, part of which reads as follows: "The telescope shows an irregular branching mass of greenish haze, in some directions moderately well defined where the dark sky penetrates it in deep openings; in others melting imperceptibly away...." Norton's account was similar: "A greenish, irregular, fan-shaped mass." Holyoke made the interesting comment that the nebula "seems to grow while you watch it". And finally, Pickering — from his site in Jamaica — considered this object "undoubtedly the finest and most detailed of all the nebulae north or south". Despite its distance of 1,500 light-years, its glory can easily keep you at the eyepiece half the night. Need we say more?

Orion brings to mind a famous painting by D. Owen Stephens entitled "Orion and Sycamore". It shows the mighty hunter amid the leafless branches of a tree on a midwinter night, with some of its stars blocked from view. Painted along the border is the thrilling and provocative caption: "Oh Glorious Geometry! To hide a Sun behind a Twig."

Celestron® 14 Schmidt-Cassegrain Telescope

Whirlpool Galaxy M51
Celestron 14 photograph

Send $2.00 for 32-page illustrated color catalogue on how to select and use a Celestron telescope . . .

Celestron

Celestron International
2835 Columbia St. Box 3578B
Torrance, CA 90503
(213) 328-9560